



## **The Effect of Pivot Bearing Assembly Process on Natural Frequency of Actuator Arm**

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### **Abstract**

The hard disk drive manufacturers are now very concerning of the vibration in each element of the HDD, especially, the resonance in the actuator arm. The resonance in the actuator arm could lead to the read-write error or media's surface damaging, which effect directly to the efficiency of the HDD and its reliability. To control the natural frequency of the actuator arm, various parameters are concerned. The components are made very precisely. The parameters of the manufacturing process are strictly controlled. The very little non-conformance parameters could lead to the quality problems of finished goods.

The pivot bearing assembly process is considered as an important factor of the variation of the actuator arm's natural frequency. To withhold the pivot bearing and the ACA (Arm Coil Assembly) together, the most common methods used by the HDD manufactures are tolerance ring insertion and glue injection. The tolerance ring, which is acting like a group of compressed springs, creates friction between the bearing and the actuator arm. With the created friction, the pivot bearing and the ACA can be fixed together during the operation. The tolerance ring compressive forces react directly on the inner surface of the actuator arm. To control the friction and the compressive forces, HDD manufacturers have to control many parameters e.g. dimension of the tolerance ring, bore diameter of the ACA, and the insertion force. This paper presents the study of vibration in each element of HDD, especially the resonance in the actuator arm. The experiment results show the relationship of variation of the pivot bearing assembly in relation to parameters that affect the modal frequency of the actuator arm.

**Keywords:** Pivot Bearing, Actuator Arm, Tolerance Ring

### **1 Introduction**

The resonance in the HDD actuator arm is needed to be avoided, since it leads to reliability and durability problem of HDD. Many parameters are considered such as geometry of the component and material properties. The

assembly method of the actuator arm is another important factor that affects the natural frequency of the actuator arm. Manufacturers invented their own designs and techniques to assembly the actuator arm and its pivot bearing. To keep the best precision and least vibration, the various

techniques of pivot bearing assembly methods have been invented [1-3]. Even they have been reduced by many methods, the natural frequency of the components exist. The HDD manufacturers live with the natural frequency by avoiding the use of those frequencies in their HDD. The notch filter and other techniques are applied. To make this idea correct, every pieces of each component supplied to the HDD manufacturer must have the invariable natural frequency.

The vibration of the HSA (Head Stack Assembly) is subjected to the vibration of every component from the suspension to the pivot shaft. The actuator arm and its related parts are manufactured under the quality control standard. The natural frequency is one of the quality control parameter.

The pivot bearing is one component that influences the natural frequency of the HSA. The pivot bearing is studied by many researchers [4-5]. The pivot bearing stiffness that affect HSA vibration is presented in [6]. The simulation of the pivot bearing is also studied [7].

This paper presents the study of vibration in the actuator arm. The comparison between experiment results and simulation result show the relationship of the pivot bearing assembly using tolerance ring in relation to the modal frequency of the actuator arm.

## 2. Tolerance Ring

The tolerance ring is metal split ring used for assembly the pivot bearing and the actuator arm together. The pivot bearing and the actuator arm is withheld by the friction at the surface of the tolerance ring as shown in figure 1. The amount of friction depends on compressive force

acted by the tolerance ring. The compressive force depends on the change of bump height, which is related to the outside diameter of the pivot bearing, inside diameter of the actuator arm, and dimple height of the tolerance ring. The compressive force also directly acts on the inner surface of the actuator arm. Then the modal frequency of the actuator arm is theoretical shifted due to the varying of the compressive force which is act as pre-stress of the actuator arm.

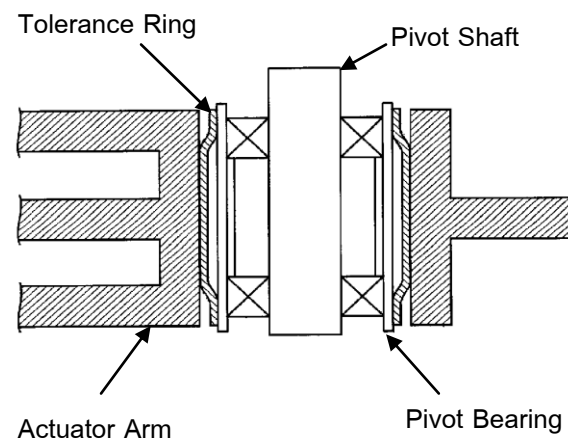


Fig. 1 Illustrate the pivot bearing assembly using tolerance ring

## 3. Experiment

The objective of this research is to identify the factors that affect the change of compressive force and its effect on the modal frequency of the actuator arm.

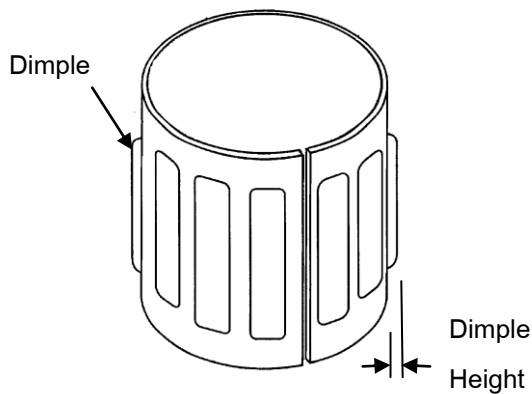


Fig. 2 Illustrate the tolerance ring

### 3.1 Assumption

The assumption of the experiment is the variation of compressive force affects the modal frequency of the actuator arm. The compressive force should have relation to various parameters such as the dimension of each element, the force feedback of the pivot bearing insertion process.

### 3.2 Experiment Setup

To prove that the dimension of parts affect directly on the modal frequency of the actuator arm, the experiment is done using one selected model of the actuator arm and vary the inside diameter of the actuator arm into five different sizes as shown in Fig.3. Each group consists of three pieces of specimen, and is called Group 1 to Group 5 respectively. The detail of each group is shown in Table.1. Group 3 represents the standard bore size. Group 1 and Group 5 represent the too tight and too loose condition. Group 2 and Group 4 represent the specimen with acceptable size. The outside diameter of the pivot bearing and the thickness of the tolerance ring were controlled by normal QC standard.

Table.1 The bore size of actuator arm

Group	Bore Size(mm)
1	(STD-0.015)±0.002
2	(STD-0.01)±0.002
3	STD±0.002
4	(STD+0.01)±0.002
5	(STD+0.015)±0.002

The specimens from each group will go through the standard assembly process. The process parameter such as the insertion force feedback has been record. After the assembly process, the actuator arm with pivot bearing was tested for their natural frequency using LDV and SLDV. The measurement setup is shown in Fig.4.

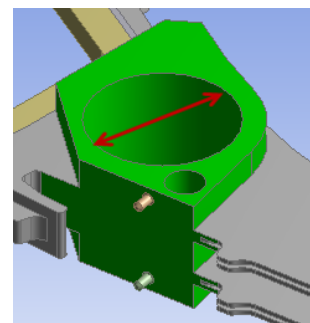


Fig.3 Illustrate ACA inside diameter

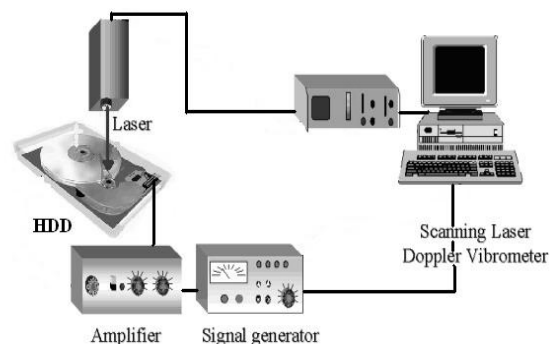


Fig.4 Measurement setup

Table.2 the Modal frequencies (SLDV)

Mode	Modal frequency of each group (kHz)				
	1	2	3	4	5
1	7.23	7.10	7.37	7.42	7.47
2	11.52	11.59	11.53	11.56	11.60
3	15.36	15.44	15.38	15.49	15.52
4	26.90	26.72	26.31	26.51	27.01
5	30.72	30.71	30.15	30.58	30.34
6	38.53	38.51	38.37	38.51	38.59
7	45.11	45.29	45.22	45.21	45.43

### 3.3 Experiment Result

Table.2 is the measurement result of the modal frequency at each mode of each group. The experiment shows that the modal frequency of mode 4 and mode 5 is significantly different in each group of specimen. Since the QC standard considers the variation of measured natural frequency of the actuator arm that is greater than 300 Hz. The mode shape of the actuator arm is illustrated by Figs. 5 – 8.

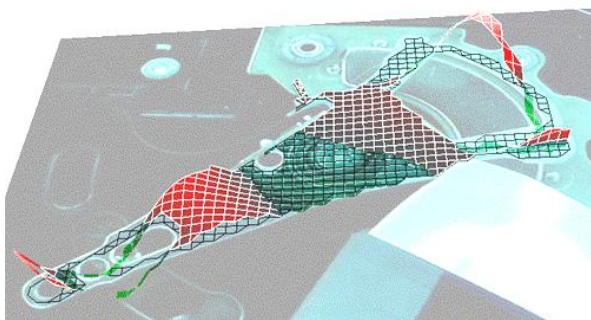


Fig.5 Illustrate the example of mode shape of the actuator arm at 15.4 kHz

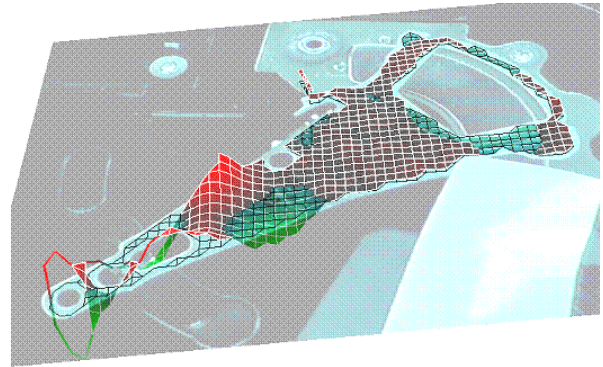


Fig.6 Illustrate the example of mode shape of the actuator arm at 26.5 KHz

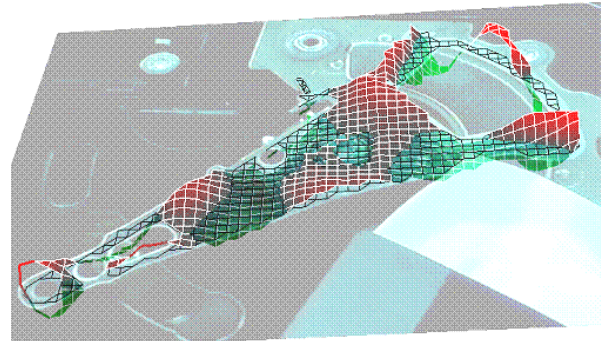


Fig.7 Illustrate the example of mode shape of the actuator arm at 30.1 KHz

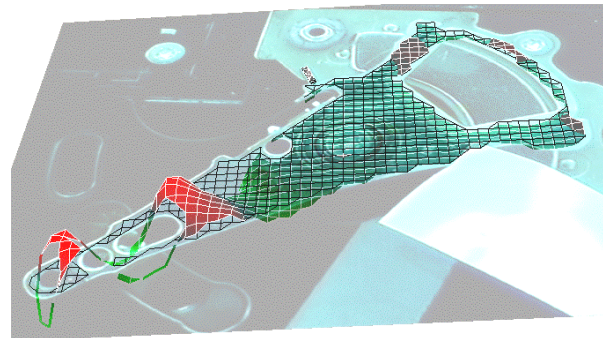


Fig.8 Illustrate the example of mode shape of the actuator arm at 38.4 kHz

As the QC standard also mentioned the install force, the pivot bearing install force is recorded and shown in Table. 3. The results show the relationship of the install force and the inside diameter of ACA

Table.3 The average pivot bearing install force

Group	Install Force (kgf.)
1	36.99
2	28.42
3	24.24
4	19.01
5	13.45

#### 4. FEM

The Finite Element Model of the actuator arm is created and is used for the modal analysis. The detail of ACA, tolerance ring, and pivot bearing are created, since the accurate result is expected.

The FEM of the APFA is developed to compare the existence of the modal frequency and the effect of varying the ACA bore size. The figure 9 illustrates the finite element model of the selected model APFA.

The FEM result presents the same mode shape but slightly different modal frequency, as shown is Table.4. The significant different of modal frequency are also in mode 4 and mode 5. The mode shape from FEM is illustrated by Figure 10. Table.5 shows the percent of different between the modal frequency from experiment and from FEM.

Table.4 Modal frequencies (FEM)

Mode	Modal frequency of each group (kHz)				
	1	2	3	4	5
1	7.17	7.21	7.26	7.28	7.33
2	11.30	11.33	11.34	11.36	11.40
3	14.76	14.84	14.94	15.09	15.12
4	24.60	24.72	24.84	25.11	25.51
5	27.62	27.71	27.96	28.25	28.58
6	35.35	35.41	35.48	35.51	35.59
7	40.91	41.19	41.25	41.31	41.43

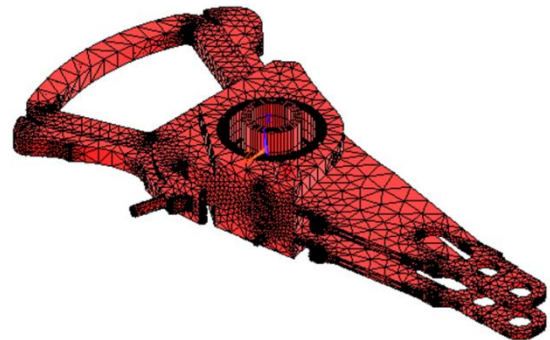


Fig.9 The finite element model of the APFA

#### 5. Conclusion

The experiment results show the relationship of variation of the pivot bearing assembly in relation to parameters that affect the modal frequency of the actuator arm. The results also show the relationship of the install force and the inside diameter of ACA. Since the install force is subjected to the friction between the tolerance ring and the inner surface of ACA then, it could be assumed that the compressive force is also subjected to the inside diameter of ACA. The significant different of modal frequency exist only in some mode. The torsion mode is the only mode shape that is found significant different. The FEM result is agree with the experiment result.

Table.5 Comparison of Modal frequency result

Mode	Modal Frequency of Group 3 (kHz)		% error
	experiment	FEM	
1	7.37	7.26	1.49
2	11.53	11.34	1.65
3	15.38	14.94	2.86
4	26.31	24.84	5.59
5	30.15	27.96	7.26
6	38.37	35.48	7.53
7	45.22	41.25	8.78

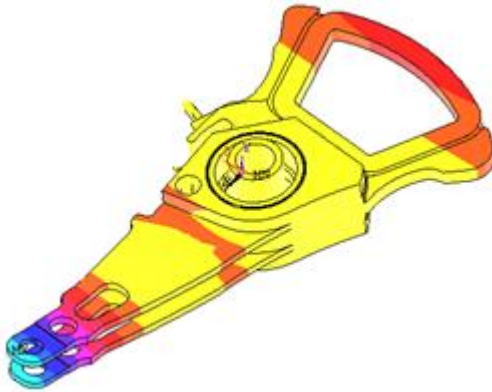


Fig.10 Illustrate the FEM arm bending mode

### 6. Further discussion

The other factors should be considered as a testing parameter. The vibration in the vertical plane should be measure. The difficulties of the experiment is controlling of the quality of the specimens, since there are a lot of part in the HDD could affect the modal frequency.

The theoretical analysis might be applied to determine the relations of the variation of parameters to the modal frequency.

### 7. Acknowledgement

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