# Three Dimensional Study of Air Flow in 3.5 inch Hard Disk Drive (HDD)

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## Abstract

The Hard Disk Drive (HDD) has also improved the development in order to gain more capacity and access time. The higher spindle motor speed is needed. The change of motor speed affects the airflow inside of the HDD. It is well known that airflow is one of the factor of the head recording vibration while the head is flying on the data track. This paper is to study the airflow in the 3.5-inch disk single head with 7200-rpm motor speed. The 3D Finite Element Model will be used in this study to compare the airflow of 2 different Head Gimbal Assembly (HGA) position models, Outside Disk position (OD) and Inside Disk position (ID). The simulation results by RNG K-epsilon found that the change of HGA position has affected the airflow inside of HDD with the velocity of air when it buffets and flow across the arm and HGA at OD is faster than the ID. The causes are due to 1. The constant angular velocity of airflow on the disk, the velocity outside is faster than inside. 2. The airflow from the outside of the disk (Voice coil area) returns in to the disk area then buffets and crosses the arm and HGA at the outside disk position. So, the arm and HGA at OD position will face the vibration problem higher than the ID position. These results will be used for the next study in the flow inducing vibration on the HGA.

**Keywords**: Hard Disk Drive (HDD), RNG K-epsilon, Head Gimbal Assembly (HGA)

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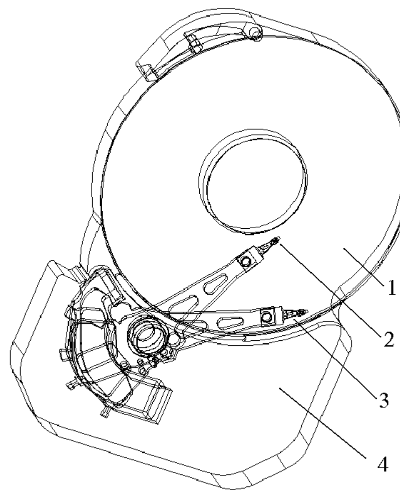
## Introduction

The most of Hard Disk drives (HDD) in the personal computer normally are the 3.5-inch platform and disk spins at its operating speed. When disk begins to spin the air inside the HDD flows around inside of the HDD. The pressure and velocity of the airflow significant affects to the vibration of the recording head. In 2001 H. Shimizu et al. (Shimizuet al., 2001) studied numerically the airflow in side HDD with large eddy simulation. In 2003 H. Song et al. (Song et al., 2004) studied flow field and particle trajectories in HDD, 3 turbulence standard models K-epsilon, RNG K-epsilon and Reynolds Stress Method are compared. M.A. Suriadi et al. (Suriadi et al., 2006) studied airflow in 1 inch HDD by standard K-epsilon turbulence model. Y. Hirono et al. (Hirono et al.,2004. ) studied on Flow-Induced Vibration Reduction in HDD using a laser dropper vibrometer (LDV) to measure amplitude of vibration. And S. Takada et al. (Takada et al., 2007) studied on Flow-Induced Vibration using LDV and static pressure sensor to measure in actual HDD. In this study focuses on the numerical simulation of airflow inside the 3.5 inch HDD. The results will be used for the next study in flow induce vibration on the HGA.

## Simulation Model of Hard Disk Drive

The 3D model of 3.5-inch HDD is simulated for studying the airflow inside HDD, The details shown as Figure 1




1- Disk; 2- Head at ID position
3- Head at OD position; 4-Base

**Figure 1.** Simulation Model of Hard Disk Drive

The major components are the Disk, Head and Base. While HDD operating the disk will rotate at a specified rotating speed then head will also move in and out for reading or writing the data. This simulation model based on the single head HDD and disk rotation speed is 7200 rpm. The space inside the HDD will define the properties as the air to study airflow. With 1.3M elements and using the turbulence model RNG K-epsilon. Boundary condition, every surface inside HDD is set as the wall except the disk and the motor surfaces are set as the moving wall at 7200 rpm.

## Method of Approach

The governing equations are Navier-Stokes equations using the turbulence model RNG K-epsilon

$$\frac{\partial(\rho k)}{\partial t} + div(\rho k U) = div\left[\alpha_k \mu_{eff}\, gradk\right] + 2\mu_t E_{ij}.E_{ij} - \rho\varepsilon \quad (1)$$

And

$$\frac{\partial(\rho\varepsilon)}{\partial t} + div(\rho\varepsilon U) = div\left[\alpha_{\varepsilon}\mu_{eff}\, grad\varepsilon\right]$$

$$+C^{*}_{1\varepsilon}\frac{\varepsilon}{k}2\mu_t E_{ij}.E_{ij} - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} \qquad (2)$$

Where $E_{ij}$ is Rate of deformation shape of element,

$\mu_{eff} = \mu + \mu_t$; $\mu_t = \rho C_{\mu}\frac{k^2}{\varepsilon}$; $C_{\mu} = 0.0845$;

$\alpha_k = \alpha_{\varepsilon} = 1.39$; $C_{1\varepsilon} = 1.42$; $C_{2\varepsilon} = 1.68$ and

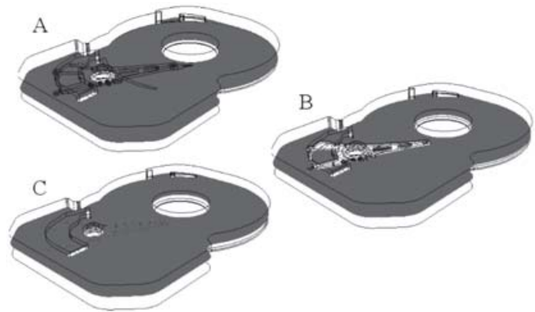
$C^{*}_{1\varepsilon} = C_{1\varepsilon} - \frac{\eta(1-\eta/\eta_0)}{1+\beta\eta^3}$; $\eta = \left(2E_{ij}.E_{ij}\right)^{1/2}\frac{k}{\varepsilon}$;

$\eta_0 = 4.377$; $\beta = 0.012$

## Results and Discussion

**Study on static pressure in HDD**

To study the airflow inside the HDD, the results in horizontal plane at different Z-height have to be plotted. In the Figure2 shows 3 different horizontal cut planes, 2.A.cut plane below actuator arm, 2.B. cut plane middle actuator arm and 2.C. cut plane above actuator arm. The values of static pressure are about 10 pa at OD and -7 pa at ID, this value is comparable in 3 different cut plane (Figure 3, 4 and 5). At the bottom of HDD (No disk area) the static pressure value is about 20 pa. Comparing between 2 actuators arm position (OD and ID position). It is to be found when the actuator arm locates at ID position, the static pressure at middle zone of the disk has higher value than OD position. Because of The airflow is blocked by the actuator arm.




A.cut plane below actuator arm, B. cut plane middle actuator arm and C. cut plane above actuator arm.

**Figure 2.** 3 Different horizontal cut planes.

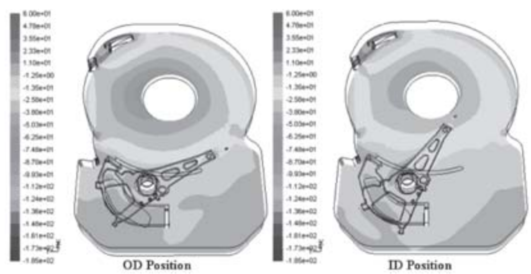



**Figure 3.** Static pressure of cut plane below actuator arm.

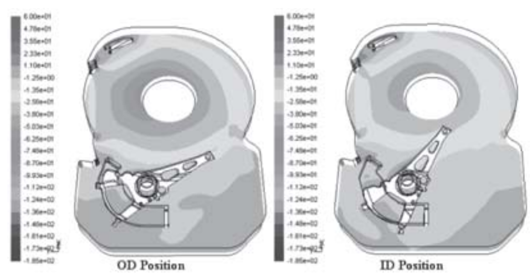



**Figure 5** Static pressure of cut plane above actuator arm.

**Table 1.** Comparison maximum of static pressure at actuator Head

| Head Position | Static pressure Max at actuator tip | Static pressure Max at actuator bottom |
|---|---|---|
| ID | -16.2 pa | 21.0 pa |
| OD | 43.2 pa | 13.5 pa |

**Study on air velocity in HDD.**

The Figure 6 shows the line plot of air velocity at the surface of the disk. The velocity at the center of the disk is the lowest; the velocity will be increased follows the radius of the disk and the highest velocity is the outer rim at 35.8 m/s. This result is similar to the result that calculated from the velocity equation.

$$v = \frac{\omega}{60} \times 2\pi r \qquad (m/s) \qquad (3)$$

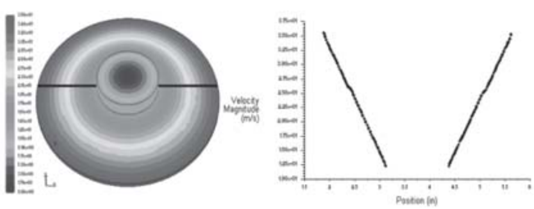



**Figure 6.** Shows the selected line and the line plot of velocity at the disk surface.

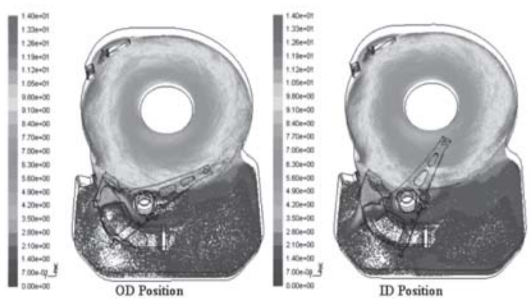



**Figure 7.** Velocity magnitude of cut plane below actuator arm

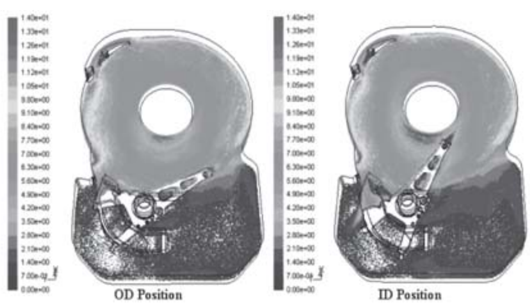



**Figure 8.** Velocity magnitude of cut plane middle actuator arm

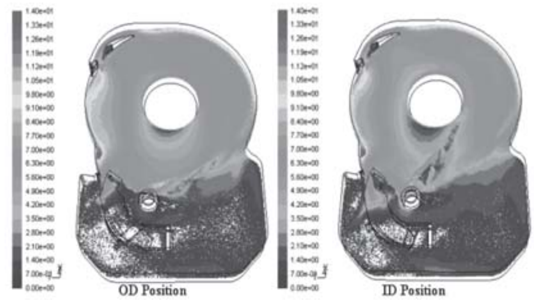



**Figure 9.** Velocity magnitude of cut plane above actuator arm

Figure 7, 8 and 9 show the velocity magnitude of cut plane below actuator arm, cut plane middle actuator arm and cut plane above actuator arm respectively. It found at the cut plane below actuator arm; which is closer to the disk surface has high velocity when compare to the higher cut plane. The velocity is decreased when the height of cut plane is increased. When the actuator arm is at the OD position; the air velocity will be perturbed the head higher than the ID position. Because the air velocity at the inner side of the disk is lower than the outer side. So, The OD position will be generated the head vibration easier than the ID position.

**Table 2.** Comparison maximum of air velocity at actuator Head

| Head Position | Maximum velocity at actuator tip | Maximum velocity at actuator bottom |
|---|---|---|
| ID | 10.8 m/s | 25.8 m/s |
| OD | 31.2 m/s | 31.2 m/s |

**Study on the flow trace of the air inside the HDD.**

Figure 10. Comparison the flow trace between OD and ID actuator head position on Horizontal plane below actuator arm, the air is flow away outward from the center of the disk till buffet to the wall around the disk. Then the air is flow to

the open wall (at the left hand side beside the disk). The air will flow outward from the disk over this open wall. The small vertex was found at this area when the actuator arm is located in OD position but not found this vertex when actuator is located at ID position. After that the air will flow toward into disk area again at the open wall at the right hand side.

At the cutting on vertical plane; the vertex of the air that perpendicularly spins with the cutting plane was found at the backside of the HDD (behind the voice coil), This vertex can be found on both OD and ID position as shown in Figure 12. The cutting plane on tip and middle of actuator, it found when the actuator located at OD position, there will be airflow from the backside of HDD flow buffet

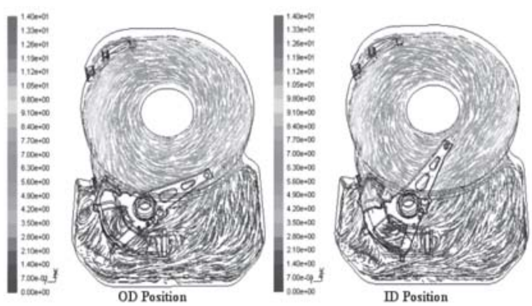



**Figure 10.** Comparison the flow trace between OD and ID actuator head position on Horizontal plane below actuator arm.

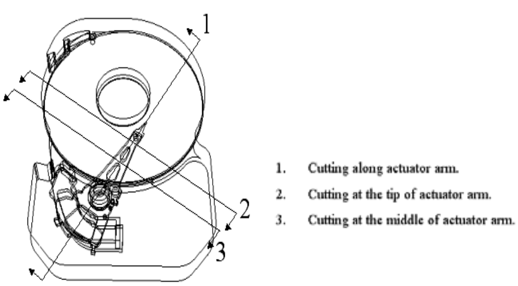



**Figure 11.** Cutting on vertical plane.

and cross pass the actuator arm to the disk area. At the ID position the airflow from the backside of HDD flow into the disk also but it not buffet to the actuator arm due to they have 2 trace of airflow buffet each other the first trace flow from the backside and the other flow along the disk radius outward from the ID to OD, as shown in Figure 13 and 14.

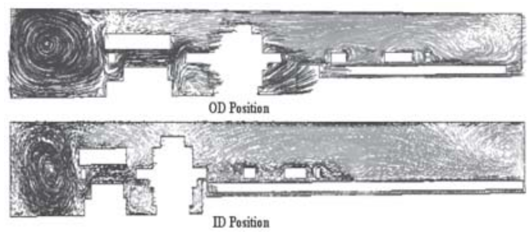



**Figure 12.** The flow trace of the air on cutting plane along actuator arm.

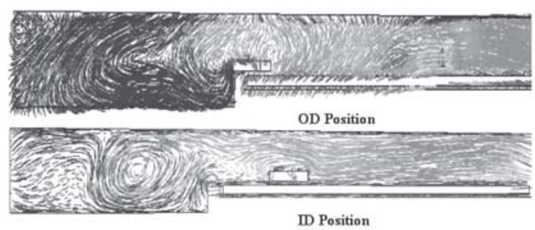



**Figure 13.** The flow trace of the air on cutting plane at tip of actuator arm.

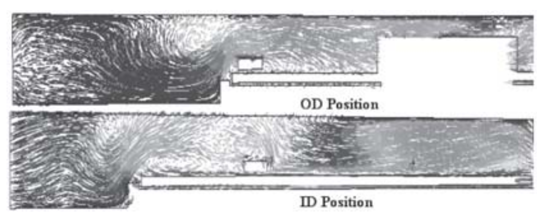



**Figure 14.** The flow trace of the air on cutting plane at middle of actuator arm.

## Conclusion

The maximum velocity of airflow from the simulation model is 35.8 m/s found at the outer rim of the disk. The mean of static pressure at OD and ID of the disk are 10 pa and 7 pa respectively. The actuator head at OD position was buffeted by airflow with higher velocity than the ID position (31.2 m/s and 10.8 m/s respectively). This will effect to the actuator head at the OD position will be more vibration than the ID position. The airflow from the backside of HDD flow buffet and cross pass the actuator arm to the disk area are also effect to the head vibration. The value of static pressure and air velocity will be used for conversion to be the force that acts on the actuator head as use as an input data for study on interactions of fluid and structure on vibrating actuator head in the next future.

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## References

Hirono, Y., Arisaka, T.,Nishijima, N., Shimizu, T., Nakamura, S. and Masuda H. 2004. "Flow-Induced Vibration Reduction in HDD by Using a Spoiler," IEEE Trans. Magn., vol. 40 No.4, July.

Shimizu, H., Shimizu, T., Tokuyama, M., Masuda H., and Nakamura, S. 2001. "Study of aero-dynamic characteristics in hard disk drives by numerical simulation," IEEE Trans. Magn., vol. 37 pp. 831-863, Mar.

Song, H., Damodaran, M., and Quock Ng, Y. 2004. "Simulation of Flow Field and Particle Trajectories in hard disk drives Enclosures," High Performance Computation for Engineered Systems (HPCES), Jan.

Suriadi, M.A., Tan, C.S., Zhang, Q.D., Yip T.H. and Sundaravadivelu, K. 2006. "Numerical investigation of airflow inside a 1-in hard disk drives," Journal of Magnetism and Magnetic Materials 303 e124-e127.

Takada, S., Kusukawa, T., Tagawa, N., Mori, A., Mizoh, Y. and Nakakita, M. 2007. "Study on flow-induced vibration of head-disk assembly mechanisms in actual hard disk drive," Springer-Verlag., Vol. 13 No. 8-10, May.