International Communications in Heat and Mass Transfer 36 (2009) 820–826

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ichmt

Heat transfer and flow characteristics in the hard disk drive tester ☆

Paisarn Naphon *, Sittisak Ratchaneekorn, Jutarat Kurujareon

Thermo-Fluids and Heat Transfer Enhancement Laboratory (TFHT), Department of Mechanical Engineering, Faculty of Engineering, Srinakharinwirot University, 63 Rangsit-Nakhornnayok Rd., Ongkharak, Nakhorn-Nayok, 26120, Thailand

ARTICLE INFO

Available online 9 June 2009

Keywords:
Heat transfer and flow characteristics
Hard disk drive

ABSTRACT

The numerical results of the heat transfer and flow characteristics in the hard disk drive tester are presented. The testing of the hard disk drive with keeping drives within the normal and high temperatures in the tester has been introduced as one of the manufacturing processes of the hard disk drive. The cooling air entering the tester is induced by the 10 axial fans into the tester and is impinged the hard disk drives and then discharged to the atmosphere. The k–ε standard turbulent model is applied to analyze the model. The results obtained from the model are verified by comparing with the measured data. Reasonable agreement is obtained from the comparison between the results obtained from the model and those from the experiment. The numerical results show that the flow and temperature distribution of cooling air are not uniformed. Which none-uniform temperature and accumulated heat are significantly factors to the failure of the hard disk drives. The results of this study are of technology importance for the efficient design and/or approved hard disk drive tester to decrease hard disk drive failure.

1. Introduction

As hard disks become more advanced, all components in these devices are required to do more and work harder to obtain the higher performance. Therefore, the hard disk drive manufacturers are developing with the advanced manufacturing techniques in order to stay competitive. In order to ensure reliable operation, hard disks are all designed and tested to function only in specific temperature ranges. Since the mechanical and electrical components within the hard disk drive, especially the produce heat, spindle motor, the biggest problem with keeping drives within operating conditions is not exceeding maximum allowable temperatures. The testing of the hard disk drive with keeping drives within the normal and high temperatures is the one of the manufacturing process of hard disk drive. However, the heat transfer and flow characteristics, the temperature distribution in the hard disk drive tester are significantly factors to the failure of the hard disk drive while testing process. Lim [1] analyzed the vibration of the hard disk drive spindle system by the finite element method. The proposed method can be applied for designing HDDs and the various other high performance computer disk drives. Wu and Bogy [2] presented two multigrid numerical schemes to solve the slider air bearing problem of hard disk drives. Luk et al. [3] applied the adhesive bonding techniques in hard disk drive head assembly. Liu et al. [4] studied on the recording track density in hard-disk drives. Effect of the butterfly mode was investigated using finite element analysis. Xu and Guo [5] experimentally studied on the residual vibration of the head actuator assembly in hard disk drives. Yuan et al. [6] numerically studied the static pressure and surface shear forces on a rotating, umbrella-deformed disk in an open shroud. Two-dimensional numerical model of the axisymmetric deformation of disk was applied to determine the fluid force distributions along the radial direction of the rotating disk. Molki and Nagalla [7] numerically studied on the flow characteristics of

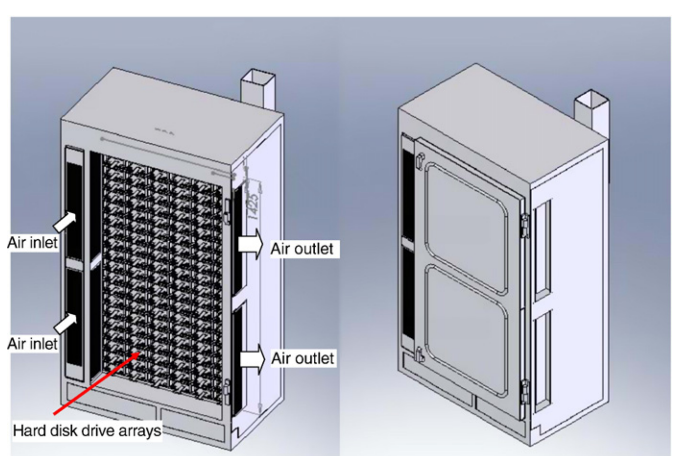

Fig. 1. Schematic diagram of the hard disk drive tester.

☆ Communicated by: W.J. Minkowycz.
* Corresponding author.
E-mail address: paisamn@swu.ac.th (P. Naphon).

0735-1933/$ – see front matter © 2009 Published by Elsevier Ltd.
doi:10.1016/j.icheatmasstransfer.2009.04.012

Nomenclature

$C_{\varepsilon l}$	turbulent model constant
C_μ	turbulent model constant
k	turbulent kinetic energy, m^2/s^2
q	heat flux, kW/m^2
$\mathbf{U}$	velocity vector
ρ	density, kg/m^3
Φ	viscosity energy dissipation function
σ_ε	diffusion Prandtl number for ε
$C_{\varepsilon 2}$	turbulent model constant
I	turbulent intensity
p	pressure, kPa
T	temperature, °C
ε	dissipation kinetic energy, m^2/s^3
μ	viscosity, kg/ms
σ_k	diffusion Prandtl number for k

Subscripts

a	air
cr	cross section
in	inlet
HDD	hard disk drive
ave	average
c	corrugated
out	outlet

rotating hard disk drive. Suriadi et al. [8] numerically investigated the airflow characteristic inside a 1 in hard disk drive. Two models with different actuator arm positions were considered. Yan et al. [9] presented the mathematical models of the spindle/disks–shaft–housing system for vibro-acoustic analysis of hard disk drives operating in idle mode.

As mentioned above, the experimental and theoretical studies have been reported concerning the hard disk drive. However, there are no papers reported on heat transfer and flow characteristics in the hard disk drive tester. In the present paper, the heat transfer and flow characteristics in the hard disk drive tester are presented. None-uniform temperature has significant effect to the hard disk drives failure while the testing process.

2. Mathematical modelling

A three dimensional model is constructed based on a real hard disk drive tester with 120 hard disk drives (20 layers and 6 rows). By considering the geometry and physical problem as shown in Figs. 1 and 2, the k–ε standard turbulence model is used to carry out the simulation. The main governing equations [11,12] can be written in the most useful form for the development of the finite volume method as

Continuity equation:

$$\frac{\partial \rho}{\partial t} + div(\rho\ \mathbf{U}) = 0 \tag{1}$$

Momentum equation:

$$x\text{–momentum: } \rho\frac{Du}{Dt} = -\frac{\partial p}{\partial x} + div(\mu\, grad\, u) + S_{M_x} \tag{2}$$

$$y\text{–momentum: } \rho\frac{Dv}{Dt} = -\frac{\partial p}{\partial y} + div(\mu\, grad\, v) + S_{M_y} \tag{3}$$

$$z\text{–momentum: } \rho\frac{Dw}{Dt} = -\frac{\partial p}{\partial z} + div(\mu\, grad\, w) + S_{M_z} \tag{4}$$

Energy equation:

$$\rho\frac{Di}{Dt} = -p\ div\ \mathbf{U} + div\ (\Gamma\, grad\, T) + \Phi + S_i \tag{5}$$

Turbulent kinetic energy (k) equation:

$$\frac{\partial(\rho k)}{\partial t} + div\ (\rho k \mathbf{U}) = div\left[\left(\frac{\mu_t}{\sigma_k} grad\, k\right)\right] + 2\mu_t E_{ij}\cdot E_{ij} - \rho\varepsilon \tag{6}$$

Turbulent kinetic energy dissipation (ε) equation:

$$\frac{\partial(\rho\varepsilon)}{\partial t} + div\ (\rho\varepsilon\mathbf{U}) = div\left(\frac{\mu_t}{\sigma_\varepsilon} grad\, \varepsilon\right) + C_{1\varepsilon}\frac{\varepsilon}{k}2\mu_t E_{ij}\cdot E_{ij} - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} \tag{7}$$

The empirical constants for the turbulence model are arrived by comprehensive data fitting for a wide range of turbulent flow of Launder and Spalding [11]:

$$C_\mu = 0.09,\ C_{\varepsilon 1} = 1.47,\ C_{\varepsilon 2} = 1.92, \sigma_k = 1.0, \sigma_\varepsilon = 1.3 \tag{8}$$

Boundary conditions:

In the present study, noslip and constant heat flux boundary conditions are applied on the test section as follows:

$$u = 0, v = 0, w = 0, q = q_{hdd} \tag{9}$$

where u,v,w are the velocities.

Initial conditions:

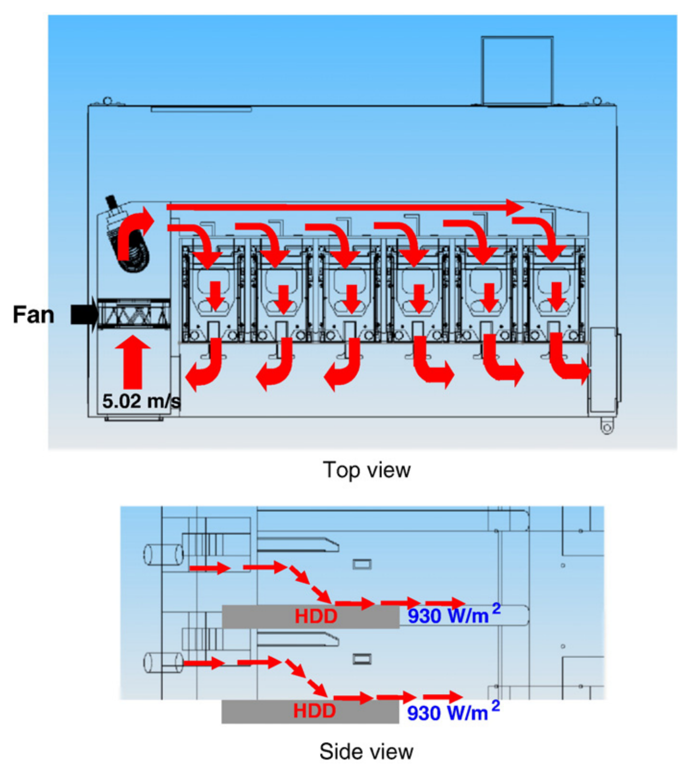

Fig. 2. Flow direction of cooling air through 2 layers of hard disk drive in the tester.