Flow Instability and Disk Vibration in a Shrouded Corotating Disk System

Shigeaki Masuda*, Shinnosuke Obi*, Mikio Tokuyama**
*Keio University, Yokohama 223-8522, JAPAN
**Hitachi Ltd., Tsuchiura, Ibaraki 300-0013, JAPAN

Experimental work on flow instability between disks rotating co-axially in a stationary cylindrical container is reported. Flow visualizations and PIV measurements of instantaneous velocity field reveal the vortical character of the unstable flow structure. Simultaneous measurements of velocity and vibration show that the flow instability is responsible for disk vibration.

***Key words**: rotating disk, flow instability, PIV-measurement, disk vibration*

1. Introduction

Flow between corotating disks enclosed in a stationary cylindrical container becomes unstable in a certain range of Reynolds number and disk spacing[1),2)]. Once this instability occurs, time dependent surface pressure may cause disk vibrations[3)]. This problem is inherent for development of hard disk drives (HDDs) of higher track density and access speed.

In the present study, the flow instability and its effect on the elastic vibration of shrouded corotating disk system are investigated. The test geometry is shown in figure 1. Flow visualizations and PIV measurements of instantaneous velocity field reveal the feature of the unstable flow structure. Simultaneous measurements of velocity and vibration show the relation between the flow instability and the disk vibration.

2. Flow Visualization and PIV

A 2.5in HDD is modified for flow visualization adopting glass disks and cylindrical acrylic shroud, both being transparent. The whole assembly is immersed in a water tank and the disks are driven by a DC motor outside of the tank. Both the disk spacing and the rotational speed are variable. The dye introduced carefully from periphery delineates a clear boundary between inner and outer regions because of weak mixing.

Figure 2 is an example of the three-leveled picture of a video frame, representing the unstable non-axisymmetric structure with the boundary of polygonal shape. Radial position of the boundary is determined as functions of the angular position for each video frames. Taking their correlation at two successive times, the speed of rotation of the structure is determined. The result given in figure 3, as well as the circumferential wave numbers, coincide well with the previous data obtained in a large scale test rig.

By employing PIV technique combined with the density correlation algorithm, the instantaneous velocity and vorticity fields are depicted from the video frames. Figure 4 shows the radial distribution of circumferentially averaged velocity. The results confirm the existence of the inner core region with a solid body rotation and the outer region with a quasi-free vortex flow. Figure 5 shows the instantaneous velocity field between the disks obtained by the PIV. In this picture, the velocity vector map seen from observer rotating with the speed of the structure is compared with the iso-contours of instantaneous vorticity normal to the surface of the disk. Two circular streamline patterns with concentrated vorticity are recognized in this picture. This result confirms the previous postulation that the unstable flow is characterized by the vortical structures with axis perpendicular to the disk and with the direction of rotation opposite to the disk itself.

3. Velocity and Vibration Measurements

Velocity fluctuation are measured by inserting a single miniature hot-wire probe between neighboring two disks. Vertical displacement of the disk surface is measured simultaneously by employing a capacitance type displacement sensor. These measurements are performed in the air test rig enclosed in an evacuated chamber so as to vary Reynolds number without changing rotational speed. Figure 6 shows the normalized rms values of velocity fluctuation of fluid and disk vibration as a function of Reynolds number. Velocity fluctuation gradually decreases with decreasing Reynolds number. More importantly, vibration amplitude also decreases in accordance with the decrease of velocity fluctuation.

Correlation measurements velocity on both side of a disk suggested that the small phase difference between instability waves on both sides is responsible for excitation of elastic vibration.

4 .Conclusions

Unstable vortical structures has been found at the current operating range of HDDs. Their axes are perpendicular to the disk and move slightly slower than the disk rotation. The disk vibration is excited by the small phase difference between instability waves on both sides of the disk.

References

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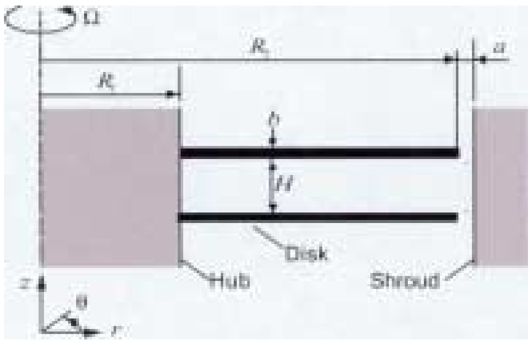

Figure 1. Test geometry

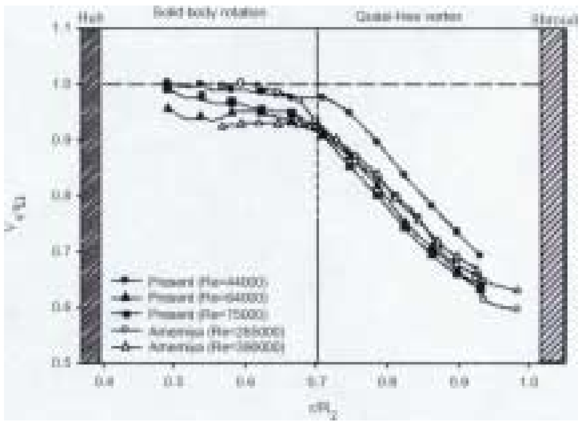

Figure 4. Radial distribution of circumferentially averaged velocity at the mid-plane between disks

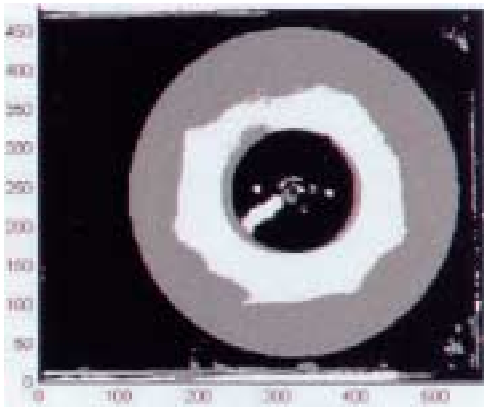

Figure 2. Time-dependent non-axisymmetric Structure

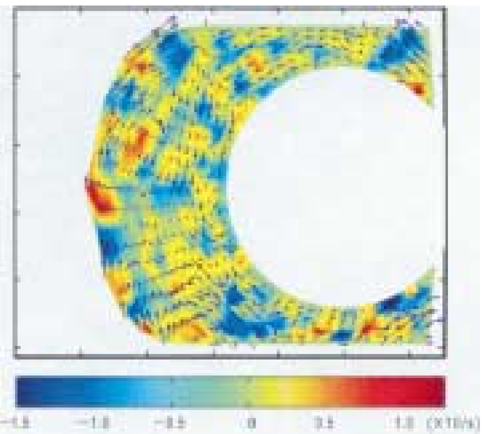

Figure 5. Instantaneous velocity and vorticity fields between disks (Re=6.4E4)

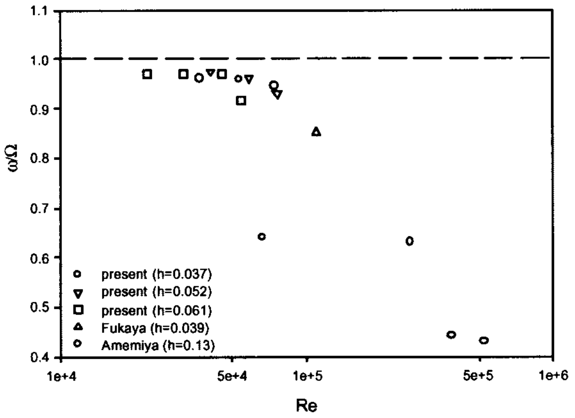

Figure 3. Rotational speed of non-axisymmetric structure

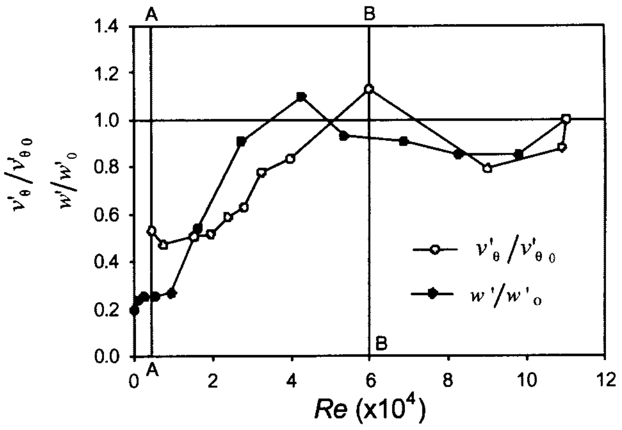

Figure 6. Velocity fluctuation and disk vibration