Experimental Thermal and Fluid Science 35 (2011) 1608–1620

Contents lists available at ScienceDirect

Experimental Thermal and Fluid Science

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

Turbulent flow of quadrangle mode in interdisk midplane between two shrouded co-rotating disks

Rong Fung Huang *, Min Kai Hsieh

Department of Mechanical Engineering, National Taiwan University of Science and Technology, Taipei 10672, Taiwan, ROC

ARTICLE INFO

Article history:
Received 1 March 2011
Received in revised form 5 July 2011
Accepted 28 July 2011
Available online 5 August 2011

Keywords:
Flow between co-rotating disks
Turbulence properties
PIV measurement

ABSTRACT

Particle image velocimetry (PIV) was employed to study the flow patterns, time-averaged velocity field, and turbulence properties of the flow in the interdisk midplane between two shrouded co-rotating disks at the interdisk spacing to disk radius ratio $S = 0.1$ and rotating Reynolds number $Re = 2.25 \times 10^5$. A quadrangle core flow structure rotating at a frequency 75% of the disks' rotating frequency was observed. The flow in the region outside the quadrangle core flow structure consisted of four cellular flow structures. Five characteristic flow regions—the hub-influenced region, solid-body rotation region, buffer region, vortex region, and shroud-influenced region—were identified in the flow field. Circumferential and radial turbulence intensities, Reynolds stresses, turbulence kinetic energy, correlation coefficients, as well as the Lagrangian integral time and length scales of turbulent fluctuations were analyzed and presented. Features of the turbulence properties were found to be closely related to the rotation motion of the inner and outer characteristic flow structures. The circumferential components of the turbulence properties exhibited local minima in the buffer region and maxima in the solid-body rotation and vortex regions, while the radial components of the turbulence intensity, turbulent normal stress, and Lagrangian integral turbulence time scale exhibited maximum values in the buffer region and relatively low values in the regions near the hub and the shroud.

1. Introduction

Investigations on the flow characteristics between two shrouded co-rotating disks have been motivated by the need to answer fundamental questions within the context of a variety of practical applications, e.g., design of the disk-storage devices, compressors, turbines, and other rotating machines. Theoretical and computational analyses regarding the originality of flow instability and patterns of flow between rotating disks have been performed by some investigators, e.g., Batchelor [1], Stewartson [2], Herrero and Giralt [3], and Mizushima et al. [4]. Earlier experimental studies, for instance, Lennemann [5], Kaneko et al. [6], and Akhmetov and Tarasov [7], employed flow visualization techniques to reveal the visual flow patterns. The researchers found that, at different combinations of interdisk spacing to disk radius aspect ratio S and rotating disk Reynolds number Re, the central region of the interdisk flow presents different polygonal shapes: *hexagon*, *pentagon*, *quadrangle*, *triangle*, and *oval*. Lennemann [5] performed flow visualization by seeding the water with aluminum powders so that the powders filled the space between two co-rotating disks. He reported that the primary feature of the flow in the plane between the shrouded co-rotating disks is an indented core-flow structure. The central core rotated at approximately 0.8 times the disk speed. Kaneko et al. [6] observed a bumpy laminar core that extended from the hub out to the middle radii of the disks. Akhmetov and Tarasov [7] reported that the polygonal curve bounding the central vortex core rotated with a constant angular velocity smaller than the angular velocity of the disks.

The velocity field was successively probed by investigators during the 1990s and 2000s [e.g., 8–14]. Abrahamson et al. [8,9] conducted velocity measurements on the water flow between the shrouded co-rotating disks at the interdisk spacing to disk radius aspect ratios $S = 0.013–0.1$ and at the disk rotating Reynolds numbers $Re = 1.5 \times 10^5–1.5 \times 10^6$. Three distinct flow regions were observed: a solid body inner region near the hub, an outer region dominated by larger counter-rotating vortices, and a boundary layer region near the shroud. Using a two-component laser Doppler velocimeter, Schuler et al. [10] and Tzeng and Humphrey [11] measured the time-averaged and root-mean-square circumferential velocity of the air flow between the shrouded co-rotating disks at the interdisk spacing to disk radius aspect ratio $S = 0.9$ and at the disk rotating Reynolds numbers $Re = 0.2 \times 10^5$, 0.9×10^5, and 2.7×10^5. The results showed that the time-averaged circumferential velocity profiles are fairly uniform in the axial direction in the space between the disks, except near the shroud where the flow is strongly sheared.

* Corresponding author. Address: Department of Mechanical Engineering, National Taiwan University of Science and Technology, 43 Keelung Road, Section 4, Taipei 10672, Taiwan, ROC. Tel.: +886 2 2737 6488; fax: +886 2 2737 6460.
E-mail address: rfhuang@mail.ntust.edu.tw (R.F. Huang).

0894-1777/$ - see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.expthermflusci.2011.07.013