A SLOWLY ROTATING STRAIGHT PIPE: EFFECT OF ROTATING RATIO

Kamyar MANSOUR, *Department Of Aerospace Engineering And New Technologies Research Center Amir Kabir University of Technology Tehran, Iran,* We consider fully developed steady laminar flow through a pipe that is rotating slowly about a line perpendicular to its own axis .The solution is expanded by computer in powers of a single combined similarity parameter introduced by [1] $K = RR_r$, keep $d = \frac{R_r}{R}$ the rotating ratio fixed where R is a Reynolds number based on axial velocity W_0 and R_r is the Reynolds number based on rotational velocity ($a\Omega$). . Then the series extended by means of symbolic calculation up to 18 terms. Analysis of these expansions allows the exact computation for arbitrarily accuracy up to 50000 figures. Although the range of exactness is almost the same order of the radius of convergence but Pade approximation lead our result to be good even for higher values of both parameters K and rotating ratio $d = \frac{R_r}{R}$

T-1C-4. INSTABILITY MODES OBSERVED IN NATURAL TRANSITION OF AN AXISYMMETRIC WAKE

S. HOSHINO, A. INASAWA and M. ASAI , *Department of Aerospace Engineering, Tokyo Metropolitan University, Japan*, Y. KONISHI, S. TAKAGI and H. SAWADA, *Institute of Aerospace Technology, Japan Aerospace Exploration Agency, Japan,* The linear instability of axisymmetric laminar wake of a body of revolution with NACA0018 airfoil cross-section is investigated under natural disturbance conditions experimentally. The experiment is carried out in a low-turbulence wind tunnel with a square test section. An axisymmetric body is suspended by the Magnetic Suspension and Balance Systems (MSBS) to avoid undesirable influences of mechanical supports on the disturbance development. In the MSBS, the model with embedded permanent magnet is kept staying at the same position in the flow by well-controlled magnetic force. The experiment is conducted at three Reynolds numbers (based on the free-stream velocity and the maximum diameter) Re = 1.4×10^4, 1.9×10^4 and 2.4×10^4, and the detailed measurements are conducted at Re = 1.9×10^4. Measurements of time-mean velocity and velocity fluctuations are done by using hot-wire anemometers. In addition to a single I-type hot-wire probe, multi-hot-wire probe which consists of six I-type sensors arranged in the azimuthal direction with equal angle of 60° is used to identify helical instability modes. Stability calculations based on the inviscid linear stability equations are also done to understand the experimental results. For this axisymmeteric model, the flow is slightly reversed in the region close to the trailing edge. The reversed flow velocity is at most 3 % of the free-stream velocity. Unlike two-dimensional wakes, the instability nature of such an axisymmetric wake does not exhibit the nature of absolute instability. That is, disturbances grow exponentially with the streamwise distance depending on the frequency. The stability analyses of the velocity profiles measured in the reversed flow region also confirm the experimental observation. Spatially-growing disturbances are found to be helical wave modes with azimuthal wavenumber of 1 as predicted by the linear stability theory for the axisymmetric wake. The most amplified frequency is close to that calculated from the linear stability theory.

10:30 ~ 12:10 (Room 104)

Rotating Flows

Session Chair : Prof. Q. H. Nagpurwala, MSRSAS/India

T-1D-1. EFFECTS OF BLADE PROFILE AND NON-UNIFORM TIP CLEARANCE ON THE PERFORMANCE OF WELLS TURBINE

M. TAKAO, *Matsue National College of Technology*, *Japan*, S. NAGATA, *Saga University, Japan*, K. TOYOTA, *Saga University*, *Japan*, M. KIDO, *Saga University, Japan*, T. SETOGUCHI, *Saga University*, *Japan,* Wells turbine is a self-rectifying air turbine which is expected to be widely used in wave energy devices with oscillating water column (OWC). There are many reports which describe the performance of Wells turbine. However, Wells turbine has inherent disadvantages: lower efficiency, poorer starting and higher noise level in comparison with conventional turbines. In order to enhance the performance of Wells turbine, some rotor blade profiles have been recommended by various researchers. According to previous studies, a symmetrical airfoil of NACA four digit series is a preferable one when the turbine is operated at low Reynolds number. Especially it has been shown that the NACA four digit series with thickness ratio of approximately 20% is a recommended one for the rotor blade. However, the stall angle of Wells turbine with this blade profile is not so high. The aim of this study is to investigate the effect of rotor blade profile on the performance of Wells turbine. The experimental investigations have been performed by use of test section with a casing diameter of 300mm. The tested turbine has 6 blades with a chord length of 90mm. In the study, four kinds of blade profile were selected and tested by model testing under steady flow condition. The types of blade profile are as follows: NACA0020; NACA0015; modified NACA0015 and modified Eppler472. Further, the effect of non-uniform tip clearance on the turbine performance was investigated under steady flow condition and the results were compared with those of Wells turbine with uniform tip clearance. The uniform tip clearances are 0.5mm and 1.0mm. The clearance in the case of non-uniform type increases gradually with chordwise, and the clearances at leading and trailing edges are 0.5mm and 1.0mm, respectively. As a result, it seems that a suitable choice of these design factors is blade profile of modified Eppler472 and non-uniform tip clearance in the study.

T-1D-2. FLOW AND DRAG CHARACTERISTICS ON A ROTATING SURFACE WITH RADIALLY MODULATED TOPOGRAPHY

M. S. YOON, *Korea Testing Laboratory, Korea*, J. S. PARK, *Halla University, Korea*, J. M. HYUN, *KAIST, Korea,* Flow in a rotating cylinder driven by the differential rotation has been studied, when the bottom end-wall disk has a sinusoidal surface roughness, i.e., $z_b = a\cdot\cos(2\pi Nr)$ where z_b denotes the local height of bottom disk surface, a the wave amplitude and N the wave number of the bottom surface. To parametric studies on various surface topography, the 40-cases of numerical computation, as varying both of wave amplitude and wave number, were performed for an incompressible steady Navier-Stokes equation. The system Reynolds number is assumed to be large, and then a boundary layer flow pattern prevails. From the linear analysis by Park, Yoon and Hyun(2008), it showed under the assumption of mild slope, i.e., $|z_b'| < O(1)$ that flow characteristics on three velocity components (u, v, w) and drag on the rotating surface could be correlated with a single parameter (aN) , not correlated independently with two parameters of wave amplitude a and wave frequency N . To test whether previous linear results are still available or not in the case of nonlinear flow by rotating wavy disk , full nonlinear numerical analysis to the Navier-Stokes equations and linear regression analysis to obtained data have performed and a comprehensive description is given on roughened surface effect of the disk to the flow fields. Dynamical ingredients of surface roughness on nonlinear flow field are qualitatively consistent with linear case, i.e., all flow characteristics being correlated with single roughness parameter (aN). However, parametric dependence shows some deviation such as all flow variables depend on $(aN)^2$ for linear case and $(aN)^1$ for full nonlinear case. Numerical solutions were acquired by utilizing the well-established SIMPLER algorithm [Patankar, 1980]. In order to deal with the sinusoidal wave surface geometry, transformations were made to introduce the body-fitted coordinates in the computational domain. Iteration was declared converged when the relative changes of the flow variables were less than 10^{-5} between two successive iteration levels. Extensive trial-and-error tests were performed for the computational grid network. The (170*130) grid system was adopted for the computation. in order to study wavy bottom disk, we also tried at the same parametric values $R_e = 3.0\times10^3$ (Reynolds number) and $A_r = 1.0$ (Aspect ratio).

T-1D-3. AN EXPERIMENTAL STUDY ON THE ASPECT-RATIO EFFECT OF A CROSS-FLOW IMPELLER

J. FUNAKI, *Department of Mechanical Engineering, Doshisha University, Japan,* Y. ONISHI, Y. IIDA, *Graduate School, Doshisha University, Japan,* A. TAKUSHIMA, *Samsung Yokohama Research Institute, Japan,* K. HIRATA, *Department of Mechanical Engineering, Doshisha University, Japan*, According to Eck (1973), the cross-flow impeller, or the cross-flow fan, was invented by Mortier in 1892, and it had been used as a fan for ventilation of mines in those days. Recently, because the cross-flow fan, or the cross-flow impeller, can easily generate almost uniform, two-dimensional, thin and wide flow, in the direction perpendicular to its axis, the impellers have been widely used for industrial equipments and home electric appliances. The purpose of this experimental research is to investigate the aspect-ratio effect on the flow around and inside cross-flow impellers. Measurements of the velocity distributions were made by PIV in order to investigate the characteristics of the eccentric vortex. The cross-flow impeller, which consists of transparent acrylics, rotated in a stationary fluid without any casing. The working fluid was air, and minute particles of olive oil were used as the tracers for flow visualization. The velocity vectors by PIV of the forward-cambered-blade impeller, show that the eccentric vortex revolves steadily at a constant speed. As the rates of the high-speed video camera are much higher than the impeller's rotation speed, we can