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Numerical Investigation of High Reynolds Number Von Karman Flow

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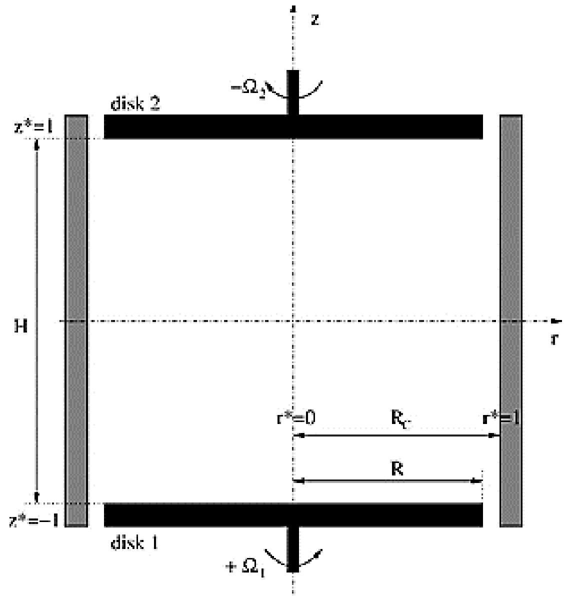
ABSTRACT

In this paper, the flow between two counter-rotating smooth disks enclosed by a cylinder is investigated numerically for different high Reynolds numbers and different ratios of the rotating speeds of two disks. Numerical predictions are based on standard k-ε model and the results are compared with experimental data i.e. velocity measurements performed at CEA (commissariate al'Energe atomique). It is concluded that turbulence can primarily affect on velocity profile.

INTRODUCTION

The flow between rotating disks, or von Karman swirling flows, occur in a variety of situations, from industrial to geophysical applications, such as rotating machining. The steady flow generated by plane disks of large diameter rotating with uniform angular velocity in contact with an incompressible viscous fluid was first investigated by Von Karman (1921). Cochram obtained a numerical solution of this problem which was improved upon by Ostrich, Thornton and Benton. The relative motion of the disks and the fluid sets up viscous stress, which tend to drag the fluid round the disks. This geometric studies are used for two aspects of developed turbulent and laminar flow. Batchelor [1] and Stewarston (1953) were two persons that have justified many works about the two aspects. In laminar case, Batchelor demonstrated that the distribution of tangential velocity is symmetrical about the midplane. In turbulent case, the flow remains axisymmetric. In this case Faure (1992) reported measurements of pressure fluctuation. In this work, numerical predictions are performed using standard k-ε turbulence model and the obtained results are compared to the velocity measurements [2] performed at CAE for turbulent flow between two counter rotating discs.

NUMERICAL SOLUTION



We consider two counter rotating disks enclosed by a cylinder. The cylinder radii is R_c = 100 mm and disks radii are R = 92.5 mm. The distance between two disks is H=180 mm. Disks 1 and 2 rotates respectively clockwise Ω_1 and counter clockwise Ω_2 where $\Omega_1 >= \Omega_2$. There are some nondimensional numbers such as $G = H/Rc$, $Re = \omega_1 R_c/\vartheta$, $\Gamma = -\Omega_2/\Omega_1$, $r^* = r/R_c$, $Z^* = 2z/H$. For numerical solution, we used 3D finite volume method. The computational domain is discretized with 200000 nodes. Nodes are closer near the disks. Turbulence modeling is based on standard k-ε (launder and Sharma). Cylinder is considered as a stationary wall boundary condition with no slip condition. The gap between cylinder and disks is assumed as a stationary wall. The disks are considered as a rotating wall with no slip condition with roughness constant 0.5. The fluid that fill between these two counter rotating disks is liquid water with density of 998.2 kg/m^3, C_p=4182 j/kg^{o}k, viscosity= 0.001003 kg/(m.s).

RESULTS

A shear layer develops in the equatorial plane. This is perceptible in Fig.1, which presents axial variations of the tangential velocity component for Γ = -1, Re=6.25×10^5, G=1.8 at various radial locations in the range r*=0.346-0.865. As illustrated in this figure, the tangential component is quite weak except in two very thin boundary layers, which developed on each disks. For r*<=0.476 a quasi-zero tangential velocity enclosed by two boundary layers on each disks is observed. Also r*>0.476 is characterized by a weak but nonzero tangential velocity component. A good agreement between the numerical results and the experimental data is obtained. Also the velocity profiles at different Re numbers are investigated. As shown in Fig. 2, low Re number has a laminar velocity profile and the profile changes dramatically due to Re increment.

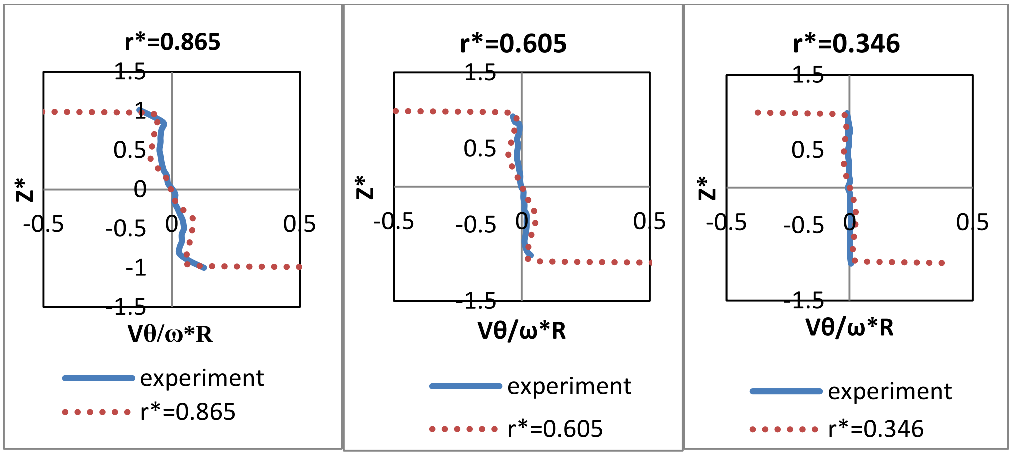


Figure 1. Axial profiles of the tangential velocity component for Γ = -1, Re = 6.28×10^5 and G = 1.8

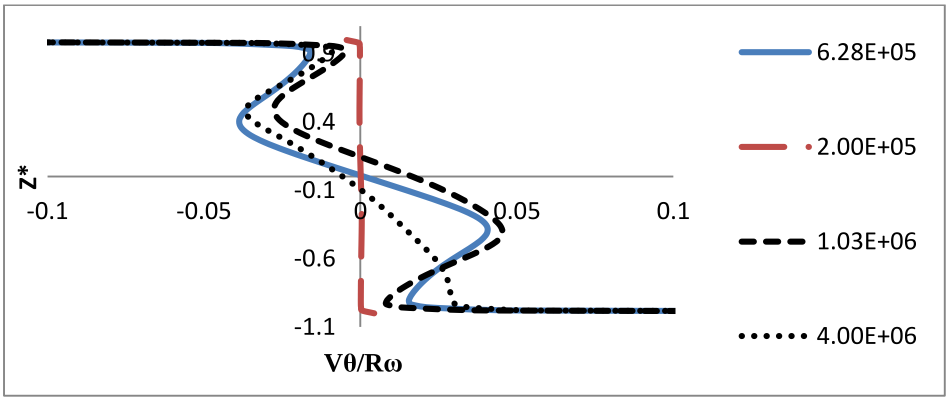


Figure 2. Axial profiles of the tangential velocity component for Γ = -1, r*=0.476 at different Re

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