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The structure of flow over the heated rotating plate.

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1.INTRODUCTION

A flow over the rotating plate is often studied to understand the instability mechanisms present in a three-dimensional boundary layer. This configuration can realize a wide range of Reynolds number so that many investigations have been also reported about laminar-turbulent transition[1][2]. On the other hand, it is well known that a flow structure over the heated rotating disk is affected with the natural convection and centrifugal force of rotation plate. However, in this flow field, there is three-dimensional boundary layer as mentioned above so that it is difficult to clarify the mechanism in quantitatively. Especially, Ogino et al.[3] showed the vortex structure when the free convection govern the flow field. To clarify the relation between the free convection and a flow by centrifugal forced, it is necessary to measure a velocity profile over a flow field.

In this investigation, we measured velocity field on a heated rotating disk with attention to the three-dimensional boundary layer. Especially, we discuss about a relation between a radial flow by centrifugal force and an axial flow by natural convection.

2.EXPERIMENTAL EQUIPMENT AND METHOD

Experimental equipment is shown in Fig.1. The rotating plate with heater and thermocouple integrated(Cu-Co) inside has a diameter of 170mm and made of copper. The heater (200V-20A) was fixed by an adhesive with high thermal conductivity onto the copper and covered by thin insulation. The heater was connected with the transformer through the slip ring as shown in Fig.2. Rotational unit was connected with the motor by a rubber belt and maximum rotation speed is 200rpm.

The UVP monitor used in this experiment is model X3-PS, and a basic frequency of transducer is 4MHz. A Nylon powder (a diameter of 50 μm, density is 1.02) was used as a tracer. The schematic of the measuring line is shown in Fig.3. The transducer was set to measure three components of velocity (circular, radius, and axis direction) to clarify the three-dimensional structure. The control parameter of a flow is $Re=\Omega r^2/\nu$ (where Ω is a angular velocity, r is distance from center of the disk and ν is a kinematic viscosity) as rotation and $Gr=d^3 g\beta(\theta-t)/\nu^2$ as natural convection (where θ is a temperature of the surface of the disk and t is a temperature of a water, d is a diameter of the disk).

3.RESULTS AND DISCUSSION

A mean velocity profiles of v_r-component are shown in Fig.4(a)-(c). Rotating speed is 50rpm and Re=0 to 3.1×10^4. A difference of temperature are (a)0℃, (b)20℃ ($Gr=5.96\times10^8$), and (c)40℃ ($Gr=2.14\times10^9$). This velocity component is generated by the centrifugal force of rotating plate and velocity component is clearly decreased due to free convection generated by temperature gradient. When the rotation speed is 50rpm and difference of temperature is 20 degree, the velocity component of centrifugal force can be observed at 5mm upward from the surface of the plate, however it can not be observed above this region. When a difference of temperature is 40 degree, velocity component can be observed only at 1mm from the surface. In a case of fast angular velocity, v_r-component can be observed at the upper region of surface of the plate. As a result, it can be considered that the radial direction is controlled by Reynolds number more than Grashof number at where Reynolds number is large (r is large).

Those results clearly show that natural convection affects to a velocity component of centrifugal force largely. We will measure velocity component of circular and axial direction for various rotation speed and a difference of temperature and will clarify the structure of three-dimensional boundary layer and relation between free convection(Gr) and flow of rotation plate(Re).

REFERENCES

[1] Balachandar, S. Streett, C. L. and Malik, M. R., J. Fluid Mech., 242, p323, 1992

[2] Littell, H. S. and Eaton, J. K., J. Fluid Mech., 266, p175, 1994

[3] Ogino, F., Inamuro, T.. Saito, Y. and Saito, A.,, 34th National Heat Transfer Symposium of Japan. p605, 1997 (in Japanese)

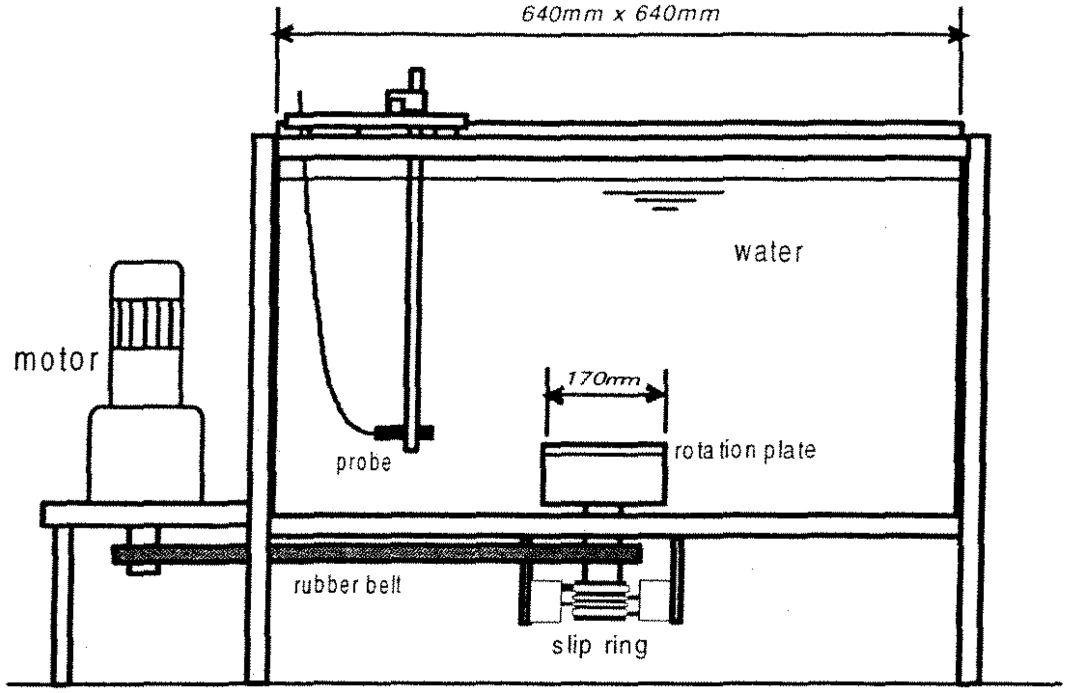

Fig.1 Experiment equipment

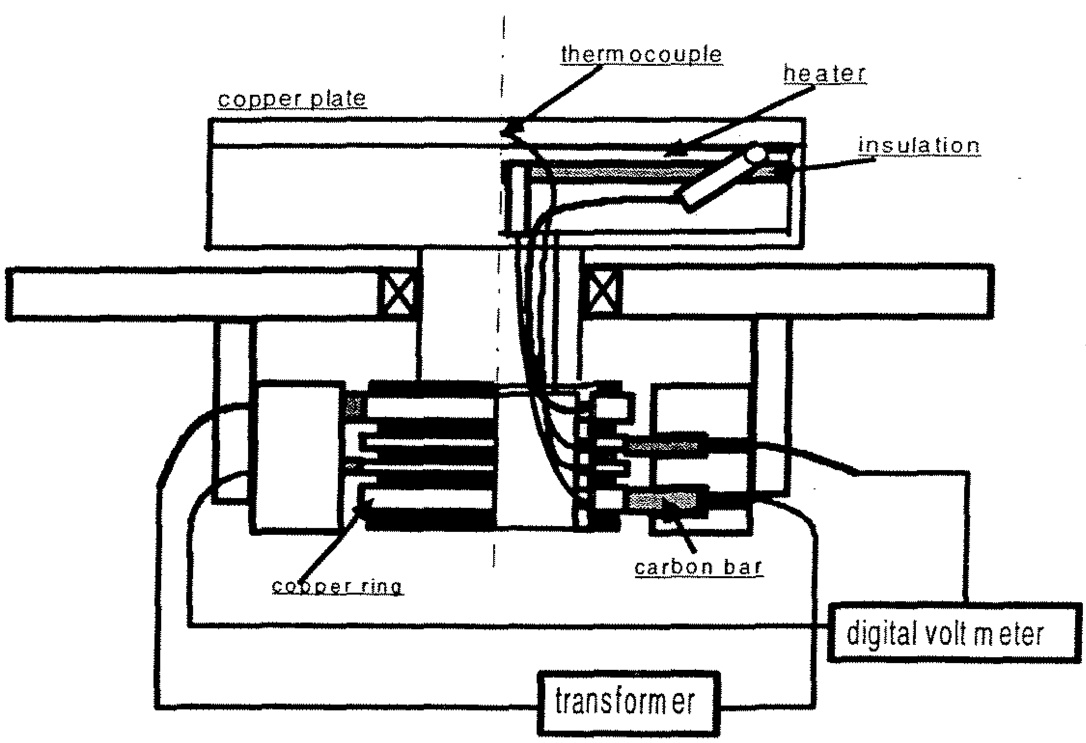

Fig.2 Slip ring detail

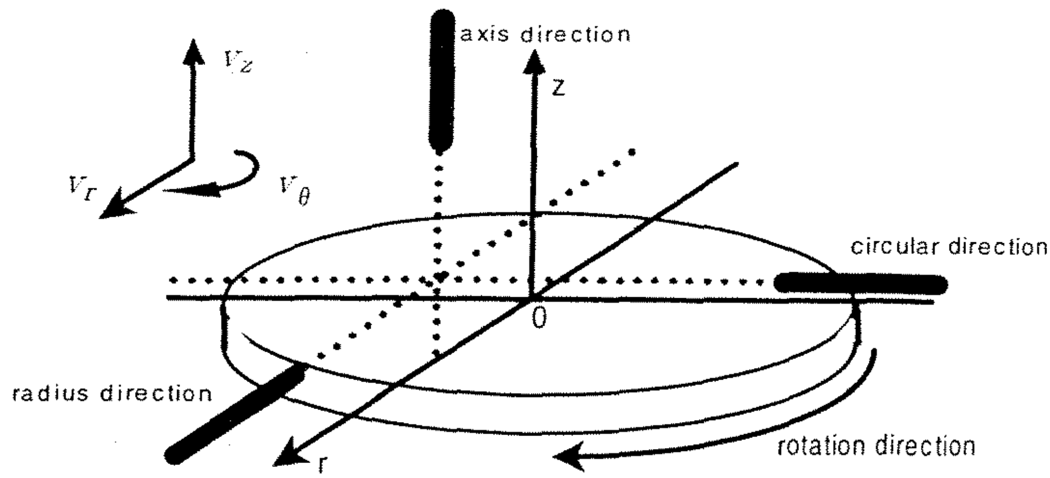

Fig.3 Probe directions

(a) 50r.p.m Gr=0

(b) 50r.p.m $Gr=5.96\times10^8$

(c) 50r.p.m $Gr=2.14\times10^9$

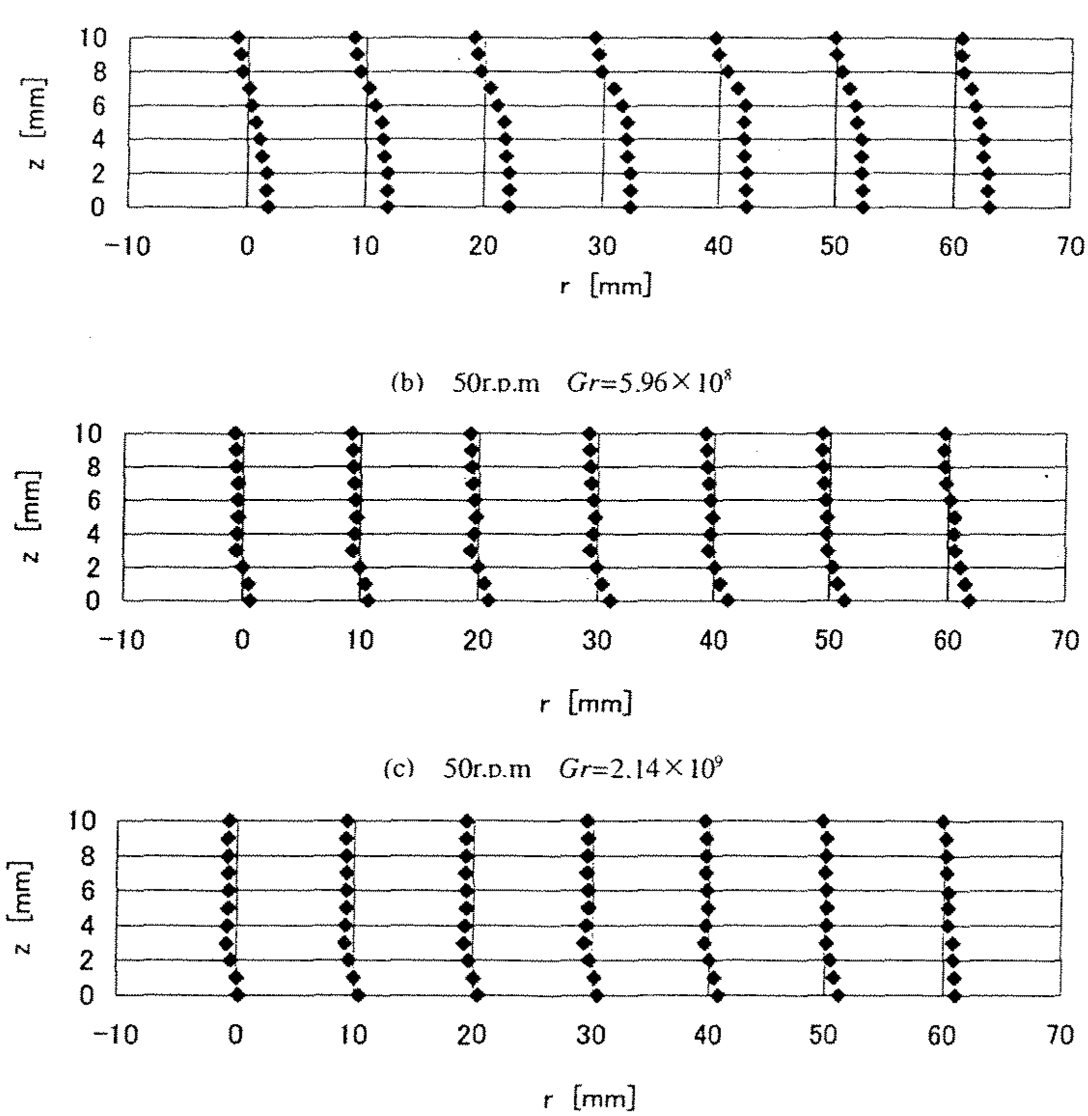

Fig.4 Mean velocity profile of v_r-component