Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

MIS21-P06 Room:Convention Hall Time:May 22 18:15-19:30

Boundary layers of an axisymmetric flow in a cylindrical tank with a rotating bottom

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In an image from the spacecraft Cassini, hexagonal flow pattern around Saturn's pole is observed. In typhoon images in meteorological sattetiles, we often find typhoon eyes with polygonal shapes. In the terrestrial and planetary atmospheres, non-axisymmetric flows are often formed in axisymmetric environments

Such a breaking of axisymmetry is realized in a simple laboratory experiment: water in a cylindrical tank is driven by a rapidly-rotating disk at the bottom. In this experiment, not only flows with polygonal patterns are observed but also hysteresis between axisymmetric circular flow and eliptical non-axisymmetric flow, and excitation of a large amplitude wave propagating along the side wall, on which we have been reported.

When we understand the mechanism of these phenomena, however, we must know the axisymmetric flow realized under this condition in spite that the phenomena themselves are not axisymmetric, since we should consider the mechanism based on the basic axisymmetric flows. Therefore, we tried to obtain analytically the axisymmetric flow in a cylindrical container with a bottom rotating in a constant angular velocity.

It is impossible to solve the exact solution of the flow, but we successfully obtained the approximate solution under the condition that the Ekman number is small with help of boundary layer theory. The flow is solved by dividing the flow in the cylindrical container into six regions with different balances: (i) inner region with rigid rotating flow, (ii) inner region with constant angular momentum, (iii) Stewrtson's 1/4-layer between two inner regions, (iv) Ekman layer near the rotationg bottom, (v) boundary layer near the side wall, and (vi) corner region where the side wall and the bottom disc meets.

In particular, we estimated the flow flux of the meridional circulation by integrating the flows obtained in each region, described the whole features of the axisymmetric flow.

Keywords: axisymmetric flow, rotating flow, boundary layer