Geophysical Research Abstracts, Vol. 7, 08002, 2005
SRef-ID: 1607-7962/gra/EGU05-A-08002
© European Geosciences Union 2005

Small scale measurement and theoretical characterization of the flow at a flat and wavy water-sediment interface

A. Goharzadeh, A. Saidi and A. Khalili
Max Planck Institute for Marine Microbiology, Celsiusstr. 1, 28359 Bremen, Germany (akhalili@mpi-bremen.de)

1- Introduction

The benthic boundary layer (BBL) is a thin layer at the seabed, which combines the water column from top with the sediment layer from below. The role of BBL in the biological, chemical and physical processes at the sediment-water layer has been recently recognized [1]. Therefore, the hydrodynamics involved at the interface has become a key factor in understanding many of these processes. One of the important questions, among others, is the thickness of the transition layer, which adjusts the flow in the water layer to the Darcy layer underneath. In this study, we report the results of a non-intrusive optical approach using particle image velocimetry (PIV) and refractive index matching (RIM) to visualize the interfacial flow in a rectangular horizontal open channel filled with a porous matrix and its overlying fluid layer. Based on the velocity profiles, an estimation of the transition layer, also known as Brinkman layer, is obtained. In addition, a new theoretical approach based on depth-dependent permeability and viscosity is performed that agreed well with our experimental results.

2- Results

The experimental setup is a rectangular horizontal open channel filled with a porous matrix and its overlying fluid layer. The 2-D velocity measurements in the interfacial region were performed. It was observed that the horizontal component of the velocity decreases continuously from the fluid layer to the porous layer. The thickness of the transition layer is estimated and its relation to the permeability, the matrix grain size and the morphology of the permeable interface is studied. The striking result found experimentally was that the thickness of the transition layer was of the order of the grain diameter, and hence, much larger than the square root of the permeability as predicted by previous theoretical studies [2-4].

A theoretical approach was also made to provide suitable models for the changes of permeability and effective viscosity in the transition layer. Afterwards, using only the experimental value of the interfacial velocity in each of our experiments, the flow field inside the transition layer (or Brinkman layer) and its thickness were predicted. In the analysis presented here, no assumption on a given thickness, δ, is made. The only assumption [5] is on the form of the changes of permeability$k(y)$ and viscosity $\mu_{eff}(y)$ in this region. We obtained a modified equation for the fluid flow in the transition layer, which, with its appropriate boundary conditions and this equation has been solved numerically. In the solution process, first a δ is assumed, then, the velocity profile is calculated. The resulting iterative procedure converged in all cases. The agreement between experiments and model was satisfactory.

3- Conclusion

Using the refractive index matching (RIM) and particle image velocimetry (PIV) we investigated a 2D flow field at the interface between a porous matrix and its overlaying fluid layer. From the averaged velocity profile, it was observed that the horizontal velocity profile decreases continuously when moving downward from fluid into the porous layer. The experimental data clearly indicate the existence of a transition layer, which is characterized by drastic decrease of velocity in a matching zone between the pure fluid and the Darcy region. The length scale of the transition layer was found to be of the order of grain diameter and much larger than the square root of the permeability. The shape of the sediment permeable interface influences the averaged velocity profile. Allowing the variation of permeability and effective viscosity in the transition layer, the new theoretical study presented seems to predict the transition layer thickness much more accurately than previous theoretical studies.

References

1. Jorgensen, B. B. “Life in the diffusive boundary layer”, The Benthic Boundary Layer; Transport Processes, Oxford University Press, 2001.

2. Kaviany, M. “*Principles of heat transfer in porous media”*, Springer-Verlag, New York, 1991.

3. Neale G, Nader W. “Practical significance of Brinkman’s extension of Darcy’s law: Coupled parallel flows within a channel and a bounding porous medium”, *Canad. J. Chem. Eng.,* **vol. 52**, pp. 475-478, 1974.

4. Beavers GS, Joseph DD. “Boundary conditions at a naturally permeable wall”, *J. Fluid Mech*., **vol. 30**, pp. 197-207, 1967.

5. Goharzadeh A., Saidi A., Khalili A., “An experimental investigation of the Brinkman layer thickness at a fluid-porous interface” IUTAM-Symposium 2004, Kluwer, will be published in spring 2005.