



Effective Surface and Boundary Condition for Heterogeneous Salt Media with Insoluble Material

Jianwei Guo, Stéphanie Veran-Tissoires, Michel Quintard

► To cite this version:

Jianwei Guo, Stéphanie Veran-Tissoires, Michel Quintard. Effective Surface and Boundary Condition for Heterogeneous Salt Media with Insoluble Material. 5th International Conference on porous media & Annual meeting of the International Society for Porous Media (InterPore), May 2013, Prague, Czech Republic. pp.1-2. hal-04019325

HAL Id: hal-04019325

<https://hal.science/hal-04019325>

Submitted on 8 Mar 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Open Archive Toulouse Archive Ouverte (OATAO)

OATAO is an open access repository that collects the work of Toulouse researchers and makes it freely available over the web where possible.

This is an author-deposited version published in: <http://oatao.univ-toulouse.fr/>
Eprints ID: 9091

To cite this version:

Guo, Jianwei and Veran-Tissoires, Stéphanie and Quintard, Michel *Effective Surface and Boundary Condition for Heterogeneous Salt Media with Insoluble Material*. (2013) In: 5th International Conference on porous media & Annual meeting of the International Society for Porous Media (InterPore), 22-24 May 2013, Prague, Czech Republic.

Any correspondence concerning this service should be sent to the repository administrator:
staff-oatao@inp-toulouse.fr

Effective Surface and Boundary Condition for Heterogeneous Salt Media with Insoluble Material

J. Guo^a, S. Veran-Tissoires^{a,b}, M. Quintard^{a,b}

^a *Université de Toulouse; INPT, UPS; IMFT (Institut de Mécanique des Fluides de Toulouse); Allée Camille Soula, F-31400 Toulouse, France*

^b *CNRS; IMFT; F-31400 Toulouse, France*

Key words: heterogeneous surface, multi-scale decomposition, effective surface

Several mechanisms, such as dissolution of salt material or drying of porous media, involve transport from a heterogeneous, rough surface characterized by areas in thermodynamic equilibrium with the surrounding fluid and areas of no flux (insoluble material, solid grains in the porous medium) [1], [2]. In general, the characteristic length-scale of the surface is much smaller than the scale of the process under investigation. To deal with this multi-scale aspect, the engineering practice is to replace the heterogeneous, rough surface by a homogeneous, smooth surface, the “effective” surface, over which is applied the Dirichlet condition corresponding to thermodynamic equilibrium. This idea has been checked partially against direct numerical simulation of the small-scale problem, in particular in the case of drying problems.

In this study, we develop a more complete theory of the concept of effective surface applied to such transport problems. The typical example under investigation corresponds to the laminar flow over a soluble salt medium which contains insoluble materials. To develop the concept of effective surface we apply a multi-domain decomposition approach [3], [4], [5]. We first decompose the system, by introduction of an arbitrary interface Σ_0 , into a macro-scale subdomain Ω_0 where the variables are smooth and a series of micro-scale Ω_i subdomains which contain all the roughnesses (cf. Figure 1). We then make estimates of velocity and concentration at the micro-scale with an asymptotic expansion of deviation terms with respect to macro-scale velocity and concentration fields. Closure problems for the deviations are obtained and used to study the position of the effective surface and the related boundary conditions.

After resolution of the closure problems, it is shown that the boundary condition for Navier-Stokes equations is of the Navier type (already known from the literature), and of a mixed reactive type, for the mass balances. The effective surface can be positioned in different places, for instance in order to recover a no-slip condition. The associated surface is denoted Σ_{eff}^v , and the effective boundary conditions are

$$\mathbf{u}_0 = \mathbf{0} \quad \text{at } \Sigma_{\text{eff}}^v \quad (1)$$

$$-\mathbf{n} \cdot D \nabla c_0 = k_{\text{eff}} (c_0 - c_{\text{eq}}) \quad \text{at } \Sigma_{\text{eff}}^v \quad (2)$$

where $\mathbf{u}_0$ and c_0 denote respectively the velocity and concentration in the first order effective model, while c_{eq} is the thermodynamic equilibrium concentration, $\mathbf{n}$ is the normal vector pointing from the fluid towards the solid, D is the diffusion coefficient and k_{eff} is defined as an effective mass exchange coefficient. If one wants to recover the original equilibrium condition, the position of the related effective surface Σ_{eff}^c is different from Σ_{eff}^v . In that case we have

$$c_0 = c_{\text{eq}} \quad \text{at } \Sigma_{\text{eff}}^c \quad (3)$$

$$\mathbf{u}_0 = \mathbf{n} \cdot (\mathbf{w}_x^c - \mathbf{w}_x^v) \nabla u_0 \quad \text{at } \Sigma_{\text{eff}}^c \quad (4)$$

where $\mathbf{w}_x^c$ and $\mathbf{w}_x^v$ denote respectively the distance from Σ_0 to Σ_{eff}^c and Σ_{eff}^v . Based on numerical resolution of the closure problems, we investigate the evolution of k_{eff} and the impact of the

effective surface position, for various geometries, Reynolds and Schmidt numbers. Finally, we make a comparison between the numerical results obtained with this effective model and those from direct numerical simulations. This allows us to discuss the practical implementation of the effective surface model, in particular the optimal position of the surface. An example of the obtained concentration fields is shown in Figure 2. Concentration contours from direct numerical simulation and the first order effective model are well superposed, apart from a small entrance region where conditions for upscaling break down, which creates a small but acceptable discrepancy. This demonstrates the interest of using an effective surface model, characterized by a homogeneous, smooth surface, to reproduce in a bulk sense flows over heterogeneous, rough surfaces.

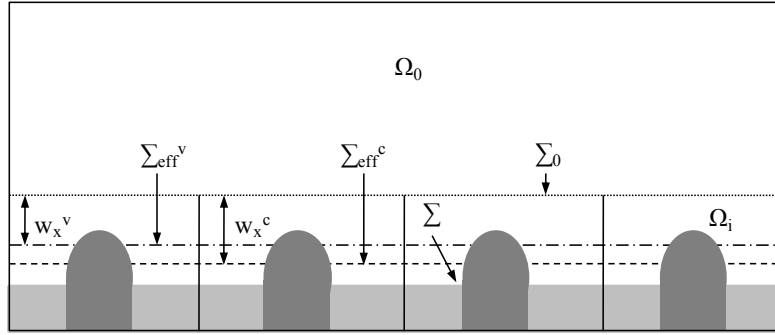


Figure 1: Definition of an effective surface.

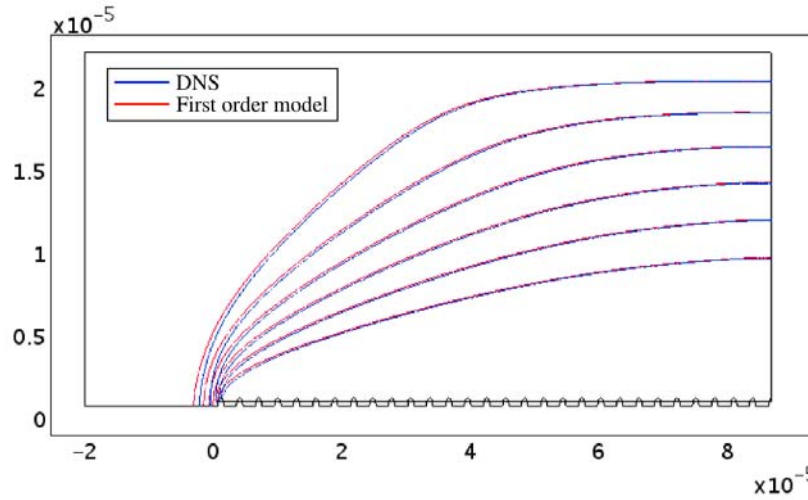


Figure 2: Concentration field contours for the initial and the effective domain, for a flow entrance velocity of 1 m·s⁻¹ and Schmidt number of 1.

References

- [1] M. Quintard and S. Whitaker. Dissolution of an immobile phase during flow in porous media. *Industrial & Engineering Chemistry Research*, 38(3), 833-844(1999).
- [2] M. Suzuki and S. Maeda, On the mechanism of drying of granular bed - Mass transfer from discontinuous source. *Journal of Chemical Engineering of Japan*, 1(1), 26-31(1968).
- [3] Y. Achdou, O. Pironneau and F. Valentin. Effective boundary conditions for laminar flows over periodic rough boundaries. *Journal of computational physics*, 147, 187-218(1998).
- [4] S. Veran, Y. Aspa and M. Quintard. Effective boundary conditions for rough reactive walls in laminar boundary layers. *International Journal of Heat and Mass Transfer*, 52, 3712-3725(2009).
- [5] C. Introïni, M. Quintard and F. Duval. Effective surface modelling for momentum and heat transfer over rough surfaces: Application to a natural convection problem. *International Journal of Heat and Mass Transfer*, 54, 3622-3641(2011).