

**HYDRODYNAMICS OF GAS-LIQUID COUNTERFLOW
THROUGH CORRUGATED PARALLEL PLATES**

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1 Introduction

Structured packings utilized in today's distillation packed towers consist of stacked units of many vertically oriented parallel corrugated plates. The "V"-shaped corrugations are oriented at a fixed angle with respect to the vertical direction, and the corrugation angle in adjacent plates are oriented in reverse direction. Points of contact, at the crests of the corrugations, between adjacent plates, form an unconsolidated porous medium with known topology. Modern structured packings have been gaining acceptance in several separation processes, particularly distillation where gas/vapor and liquid flow countercurrently through the packing. In addition, structured packings have been credited with relatively low pressure drop, high efficiency, low holdup, and higher capacity; the packing also can be made corrosion resistive.

In the past decade industry, government (ADLER *et al.*, 1998), and academia (PORTER, 1995) have extolled the need for improving distillation processes. Current modeling strategies are still inadequate since they are largely semi-empirical and prone to failure. Therefore there is considerable anticipation that novel modeling techniques with realistic predictive capabilities will impact distillation beneficially. Despite a number of efforts towards modeling gas-liquid flows in distillation towers, design and analysis of these industrially important devices remain relatively primitive when compared to prevailing modeling techniques in other industries, *e.g.*, aircraft and automobile industries.

Progress towards realistic modeling of transport phenomena in distillation towers has been hampered by exceedingly complex two-phase hydrodynamics in porous media. In spite of modeling difficulties, predicting the simultaneous motion of gas-liquid phases in a porous media of known (reproducible) geometry and topology is becoming a tractable problem. Recent advances in modeling complex flows in porous media via emerging lattice-Boltzmann methods (MAIER *et al.*, 1998; GRUNAU *et al.*, 1993) are promising techniques that can be used to simulate flows in complex geometries with a hitherto level of detail. In particular gas-liquid flows in packed towers filled with certain structured packings are viable candidates.

The purpose of this work is twofold. First, this research investigates fundamental aspects of modeling single phase—gas and liquid—flows through corrugated parallel plates. Since the crests of opposite plates make contact at a finite number of points (fig. 1.1a), a porous medium is formed possessing reproducible topology. Predictive results obtained by solving the Boltzmann equation on a suitably constructed lattice, containing the void space between the parallel plates, will be compared with visualizations through an acrylic model (fig. 1.1b) that matches the same geometry used in the simulations.

The second goal of this work is to investigate the feasibility of gas-liquid countercurrent flow in the void space of the porous medium represented in figure 1.1.

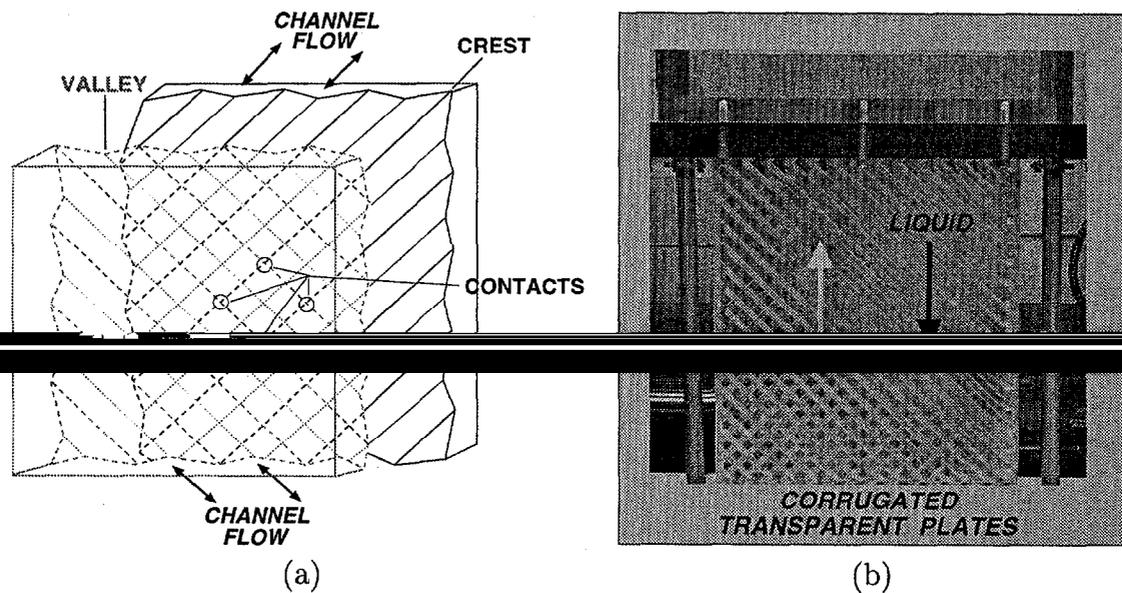


Fig. 1.1: Arrangement of corrugated parallel plates: (a) Schematic; (b) Acrylic model.

In addition, comparison with laboratory visualization of corresponding flows will be made. Satisfactory achievement of the foregoing goals will provide a solid scientific basis for future developments in modeling of flow in packed towers, and, ultimately, the complete transport phenomena of distillation in these devices.

2 Modeling

Lattice-Boltzmann methods are techniques for solving the Boltzmann equation on a lattice (ROTHMAN AND ZALESKI, 1997). These methods have made recent in-roads in the computational fluid mechanics (CFD) field, largely dominated by well-established methods, because of their simplicity of implementation and parallel nature. It has been demonstrated that certain discrete approximations to the Boltzmann equation produces an approximation to the solution of the Navier-Stokes equation—at least in the low compressibility limit. Therefore LBM can be effectively used as an alternative to traditional CFD. However, the unique salient features of LBM suitable for this research are: (i) can be simply applied to very complex geometries, for instance, flow in porous media; (ii) can be extended to simulate two-phase flows in complex geometries; and (iii) simple implementation on modern parallel computers.

Flow in packed beds with structured packing consisting of smooth parallel cor-

rugated sheets is a natural candidate for analysis by LBM. The underlying porous medium is representative of realistic packings and yet simple enough to allow modeling. In addition, a contrived experiment can be constructed to verify simulation results.

There are outstanding issues to be resolved before LBM can be employed to simulate complete transport phenomena occurring in packed towers. Notably, non-isothermal flows are notoriously problematic except in the presence of low compressibility effects and low temperature variations. Furthermore, LBM for immiscible two-phase flows with varying physical properties are not fully developed.

This research is aimed at developing a scientific basis for building modern modeling methods of flow processes occurring in packed towers. Investigations of applied nature, supported by technology development programs, are also planned for the future.

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