**Mixed wetting in porous media and percolation**

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**Abstract**

When fluid flows through the porous media, the contact angles of fluid vary with the wettability conditions. Wetting can be described as the balance between cohesion and adhesion in the contact between fluid and solid matter. The cohesive forces keep the fluid particles together, while the adhesive forces try to stick the solid and the fluid together. Whether a liquid adheres strongly or weakly depends on what is more energy efficient for the molecules. A porous medium is said to have mixed or non-uniform wetting conditions, when the walls of grains on each side generate different wetting angles for the fluid-solid interface.

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In case of two phase flow in a porous media, there is a capillary force in the pores between rock grains of similar wetting. If the wetting properties are opposite, this capillary force is negligible, which is less resistance path for the fluid to flow. This flow problem can be studied using percolation in dual lattice.

Let us consider a square lattice where the sites can be occupied with certain probability. The dual lattice of a square lattice is also a square lattice. Say, the occupied sites on the original lattice correspond to rock grains with positive wetting and the unoccupied sites correspond to rock grains of negative wetting. When there is an unoccupied site sitting next to an occupied site then we draw a bond in the dual lattice seperating them which acts as a bisector to the bond between them. In Fig.1, the sites with + sign represents a positive wetting and sites with – sign represents negative wetting. There is a bond placed in the dual lattice between a possitive and negative wetting. In this manner the flow problem gets mapped to a network of ocupied bonds in the dual lattice. These bonds in the dual lattice mark the path ways of least resistance for the fluid.

Since the network is generated by the process of separating the positive and negative wetting rock grain, the underlying structures is made up of loops and very different from that of the ordinary bond percolation cluster. In Fig.2 we show a snapshot of the bond network in the dual lattice for the occupation probability of the sites p = 0.4 for a system of size L=32. When the bond network spans the lattice. fluid can flow from one end of the lattice to other end. It is observed that when the sites are occupied at a concentration pc=0.40725 on the original lattice, the bond network produced on the dual lattice percolates. Though, the critical site concentration is much less than that of the site percolation threshold, 0.5927, the bond density on the dual lattice is found to be ≈ 0.5. When probability of the negative wetting sites fall below p = 0.407, i.e the unoccpied sites concentration falls below 0.407, the bond network doesnt percolate. This symmetical behavior is shown in Fig.3. The characteristic of the network of bonds in the dual lattice is studied by varying the occupation probability p of sites in the original lattice and determining the size distribution where τ and σ are two exponents. The order parameter for the transition of flow to non-flow goes as where β is the critical exponent of order parameter. Similarly γ is the critical exponent of the fluctuation of the oder parameter and ν is the critical exponent of the correlation length. The critical exponents are found to be β = 0.139, γ = 2.31, ν = 1.31, τ = 2.04. A finite-size scalling study is performed by varying the system size L. It is worthwhile to note that however the process to generate the bond network is much different than that of random bomd percolation, however, the exponents that characterises the flow to no flow transition in the dual lattice are found to be same as that of the ordinary percolation. Hence, the two phase flow model belongs to the same universality class of percolation.

**Keywords:** Wetting condition, capillary force, percolation, dual lattice, spanning threshold, critical exponents

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| Figure 1: bonds in dual lattice between different wettings | Figure 2: snapshot of a system 32 x 32 with p = 0.4 | Figure 3: wraping probability of the network vs occupation probabilty of sites. |