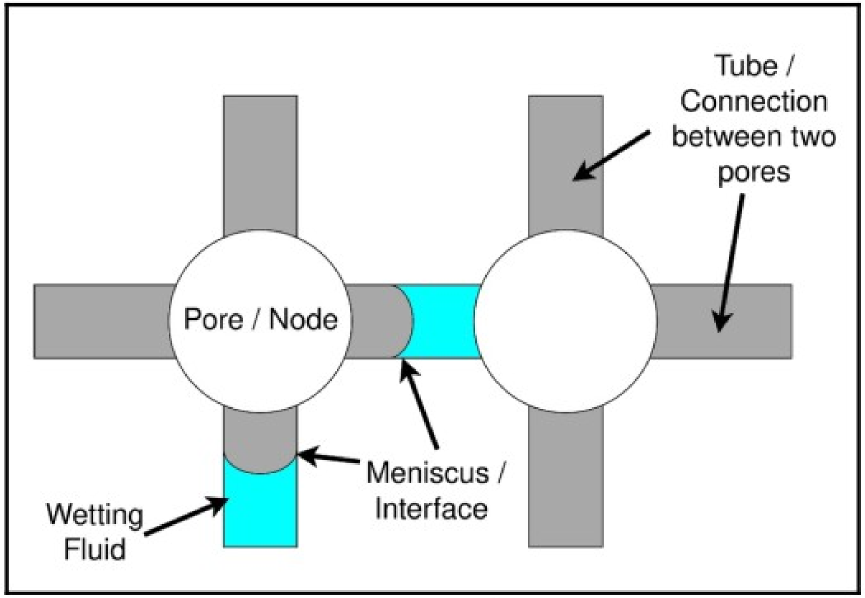


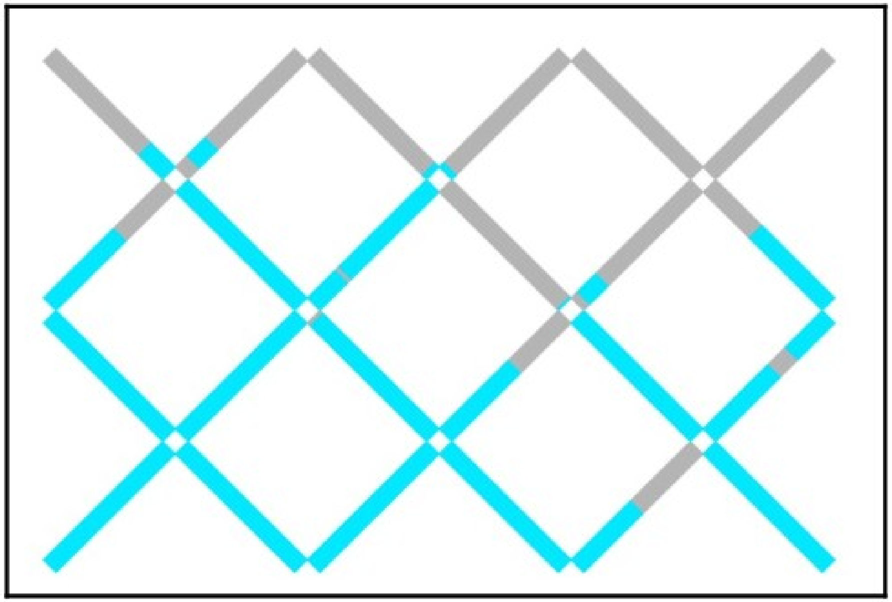

# Conference Presentation: Model of Two-Phase Flow in Porous Media

**Full title of the work:** Simulation of Two-Phase Flow in Porous Media using a Two-Dimensional Network Model


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**Organization:** Moscow Institute of Physics and Technology

**Presented at:** 65 MIPT Conference, Dolgoprudny
**Date:** 08.04.2023

# Contents

# Part-1 Introduction

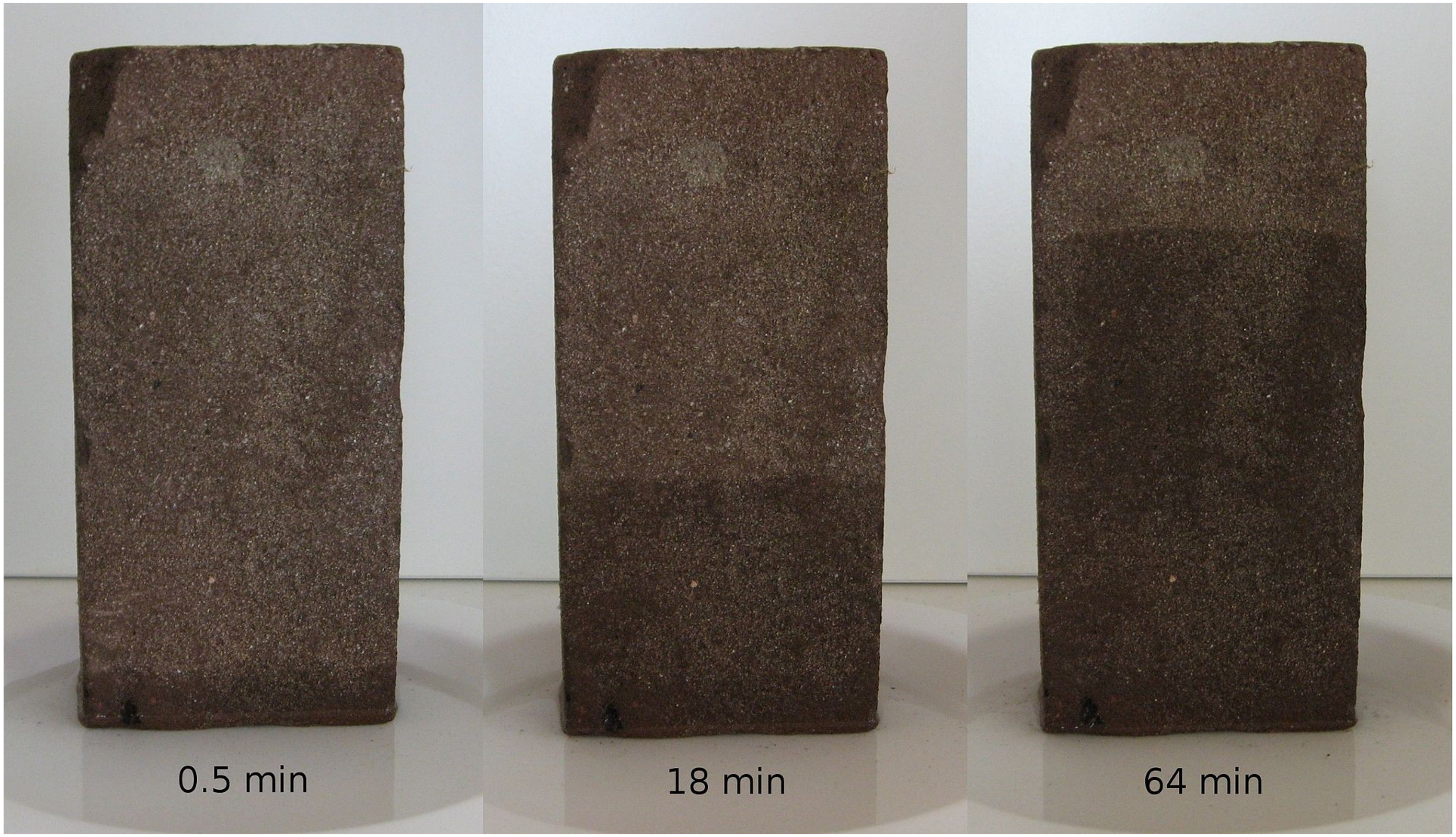
**Network Model:**

- Flow of phases in porous media
- Determination of pressure
- Determination of flow Rate
- Updating step by step

**Practical Applications:**

- Oil recovery
- Hydrology
- Electricity production (pressurized water through heated pipes -> into steam)

# Part-1 Introduction



# Part-1 Other Models

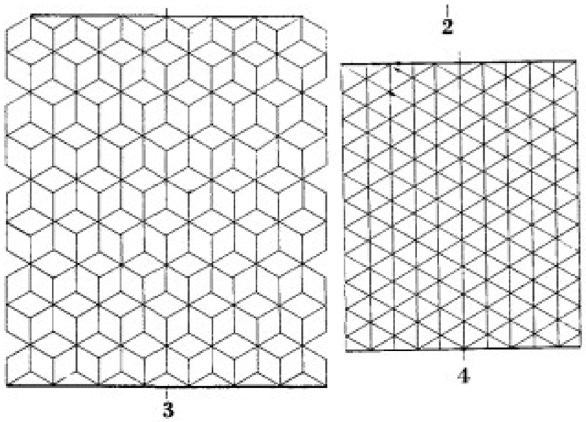



FIG. 1—SINGLE HEXAGONAL NETWORK.
FIG. 2—SQUARE NETWORK.
FIG. 3—DOUBLE HEXAGONAL NETWORK.
FIG. 4—TRIPLE HEXAGONAL NETWORK.

the same channel. Multiphase fluid flow in separate channels in porous media has been termed channel flow, while concentric flow in the same channel has been termed filament flow. The best observational support for the assumption of channel flow comes from the cinemicrophotographic studies of Chatenevar[24], and from the Stanolind group[25]. Leverett[26] has shown on theoretical grounds that the interfaces between two immiscible phases in porous media will distribute themselves so that the radii of curvature of the interfaces, $r_1$ and $r_2$, in the pore spaces will obey the LaPlace equation

$$P = \delta\left(\frac{1}{r_1} + \frac{1}{r_2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

[1] Fatt I. The network model of porous media: Model using Resistors 1956



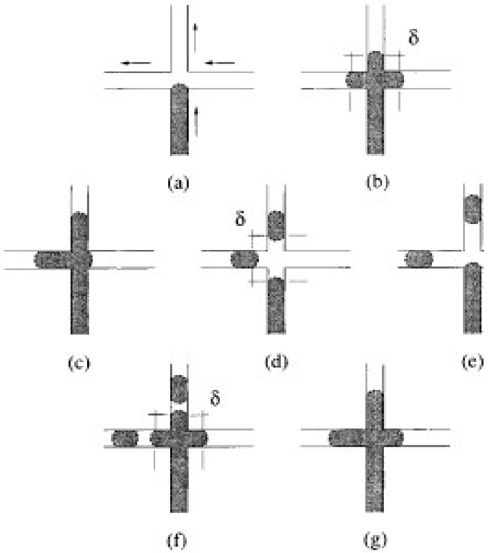



*Figure 7.* A ‘mixture’ of non-wetting (shaded) and wetting (white) which flow into the neighbor tubes. The different arrangements (a)–(g) are a result of applying the rules which are described earlier in this section. For all figures the fluids flow towards the node from the bottom and right tube while the fluids in the top and the left tube flow away from it (denoted by the arrows in (a)).

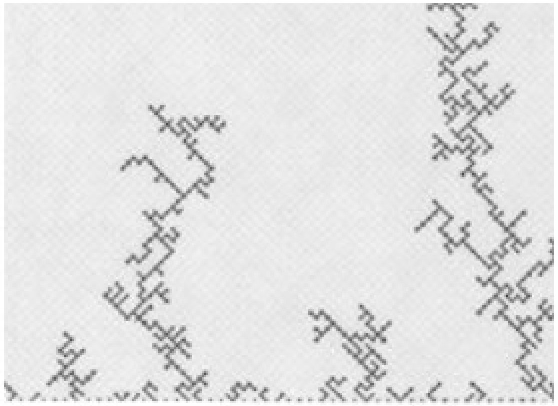


*Figure 8.* The pattern obtained of a simulation in the regin of $60 \times 80$ nodes. $C_a = 4.6 \times 10^{-3}$ and $M = 1.0 \times 10^{-}$ (black) displaces the defending wetting fluid (gray) from $7\frac{1}{2}$ h on a Cray T90 vector machine.

Aker, E., Måløy, K.J., Hansen, A., Batrouni, G.G. A two-dimensional network simulator for two-phase flow in porous media // Transp. Porous Med. 1998 V. 32 P. 163

# Part-2 General Aim

**The algorithm can be used to simulate:**

1) Saturation of a phase with respect to time
2) Model imbibition
3) The Hysteresis Curve [the pressure across the porous body reversed, total capillary pressure =f(saturation)]
4) Determination of permeability (Darcy’s law)

# Part-2 Aim and Task

**Model imbibition**

- Wetting fluid displaces non-wetting, thinner capillaries

**Description of the particular problem presented today**

- Area-1 non wetting
- Area-2 wetting
- Volume-1  = Volume-2
- Radius-1 = Radius-2 / 3

# Part-3 Tools and Methods Used

**Computer Simulation**

**Input Files:**

- Radius distribution
- Phase Distribution

**Compiled C++ Program processes**

- Solution of linear equations
- Euler Method of Integration

**Only simple Data Structures used, no external libraries**

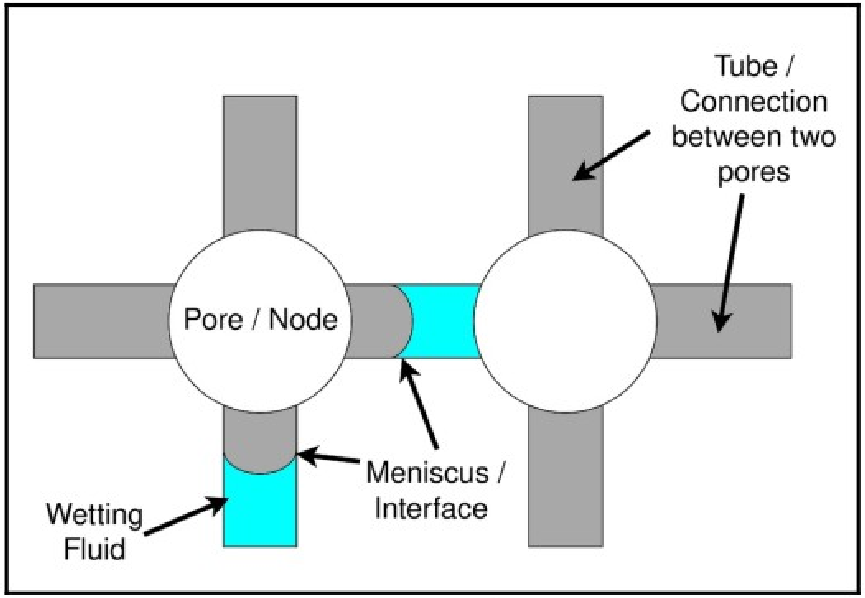
# Part-4 Work: Equations

$$\sum Q_i = 0 \quad (1)$$

$$Q = \frac{\pi R^4}{8\,Ml}\left(\Delta P + \frac{2\,s\,\sigma}{R}\right) \quad (2)$$

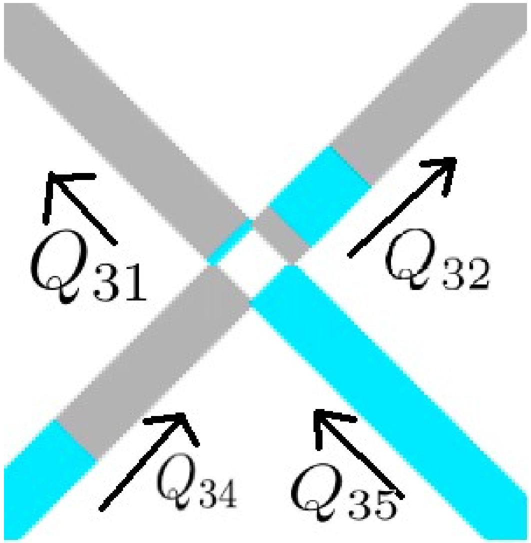
$$M = \sum \mu_i \frac{l_i}{l} \quad (3)$$

$$Q = \frac{\pi R^4}{8\,\mu}\frac{\Delta P}{l} \quad (4)$$



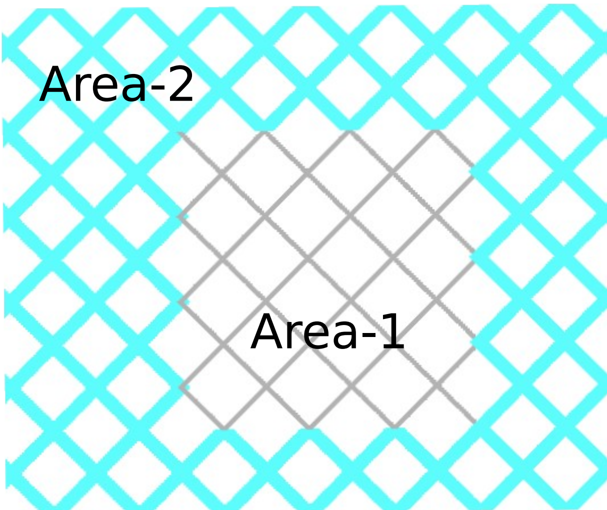
# Part-4 Work: Algorithm [3]

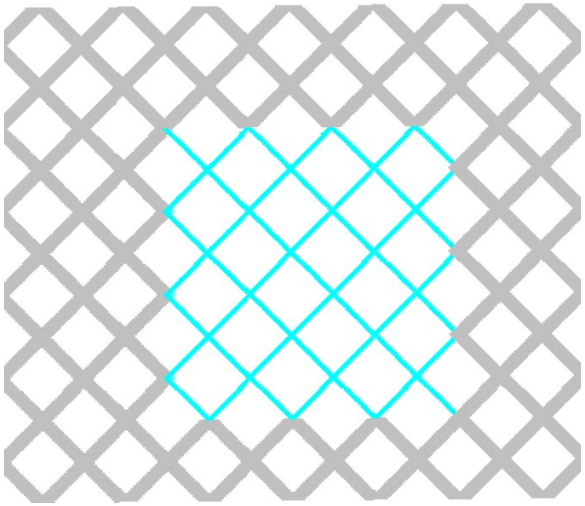
1. From (1), relates five pressures.
2. N(equations) = N(nodes in network model)
3. Equations solved using Gauss-Jordan Elimination.
4. Flow rates calculated using (2)
5. Time step is chosen according to the nearest meniscus reaching the node.
6. At each of the nodes the flow is distributed to the outgoing tubes such that the tube with the smallest radius is filled first with the wetting fluid, this is due to the favor of energy.



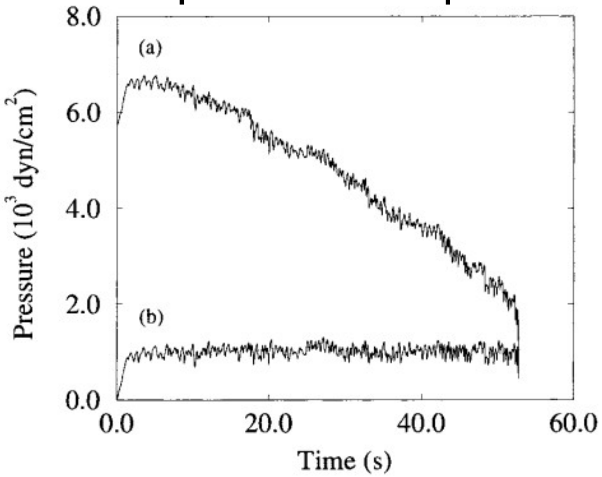

[3] Aker, E. et al, A two-dimensional network simulator for two-phase flow in porous media

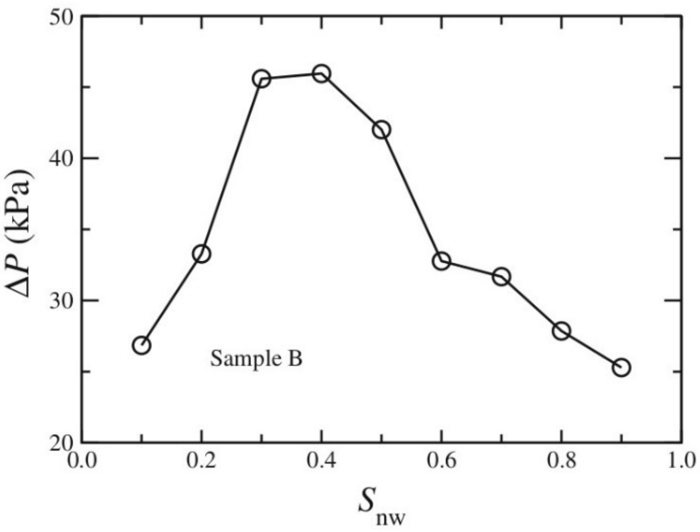
# Part-4 Work: Results



Expected Graphs



# Part-5 Conclusion

- Adjusting radius distribution, coefficient of capillary force, and viscosity: explains physical phenomena.
- Modified to the case where there are more than 4 tubes connected to a node. Example: Hexagonal Structure, 3D model[2]
- All Equations and Integration steps are linear and large network models (100 x 100) can be simulated on a personal computer.

[2] S. Sinha et al. Effective rheology of two-phase flow in three-dimensional porous media

# Part-6 References


1. Fatt I. The network model of porous media 3, dynamic properties of networks with tube radius distribution Petroleum Trans. AIME 1956. V. 207. P. 164
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