A New Pore-Network Model for Granular Media:
Application for P^c-S^w and a^{nw}-S^w Relationships

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Objectives

- **Developing an approach for constructing representative pore-network model for granular media.**
- **Simulating Pc-Sw and anw-Sw curves for air-water experiments in glass beads (Culligan et al., 2004).**

Approach

1. Developing a framework for generating the cross sections based on shape factor, number of vertices and inscribed radius using hyperbolic polygons.
2. Data acquisition using 3DMA-Rock for glass beads sample.
3. Implementing quasi-static simulations on the network.

Cross Sections Geometry

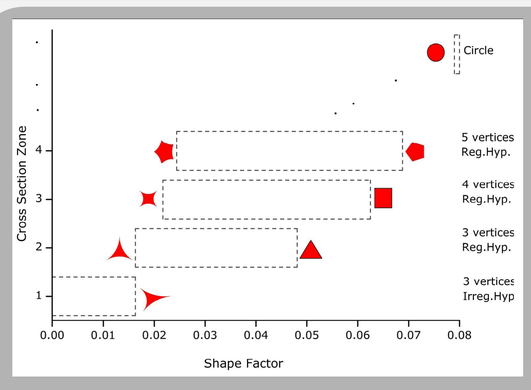


Fig 1. Range of shape factor for different classes of cross sections.

For a given shape factor, different cross sections can be selected. Usually we do not know number of vertices in cross sections for a given porous medium

We consider two different cross sections for pore throats:

1. Irregular hyperbolic triangles $n = 3$ (Fig 2)

Solving 6 equations to determine $R_1, R_2, R_3, \alpha, \beta, \gamma$

Based on shape factor (G) and inscribed circle (R).

2. Regular hyperbolic polygons $n \geq 3$ (Fig 3)

Solving 2 equations to determine R_1, φ

Based on shape factor (G) and inscribed circle (R).

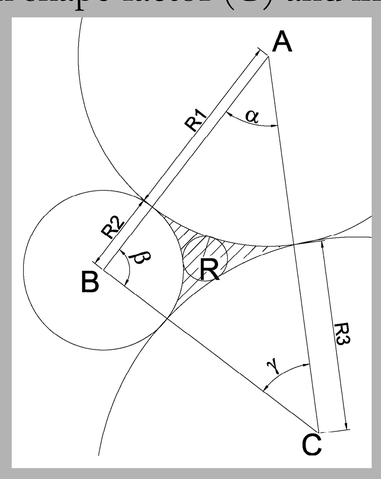


Fig 2. Irregular hyperbolic triangle for given shape factor and inscribed radius.

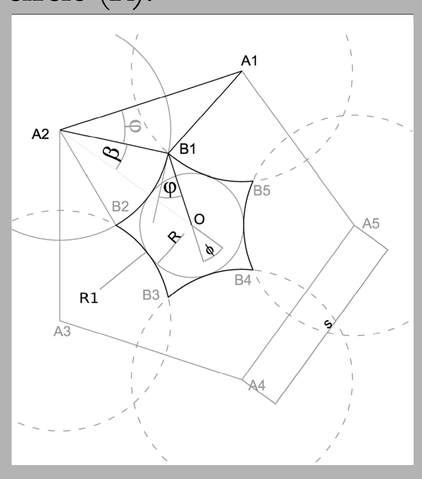


Fig 3. Regular hyperbolic polygon for given shape factor and inscribed radius.

Entry Pressures

During drainage pore throats are the governing elements. Entry capillary pressure for pore throats have been determined using *MS-P* method based on the geometries of interfaces. For irregular hyperbolic triangles (Fig 4), ten equations are solved to find $r_c, \varepsilon^i, \varepsilon^i_i, \varepsilon^i_{i+1}, i = 1,2,3 (\varepsilon^3_4 = \varepsilon^3_1)$. For regular hyperbolic polygons (Fig 5) three equations are solved to determine $r_c, \varepsilon, \varepsilon'$.

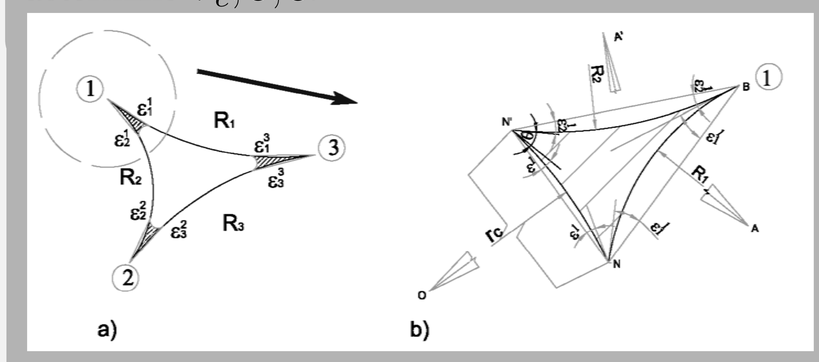


Fig 4. a) Interface geometry in an irregular hyperbolic triangle b) Interface configuration in a vertex.

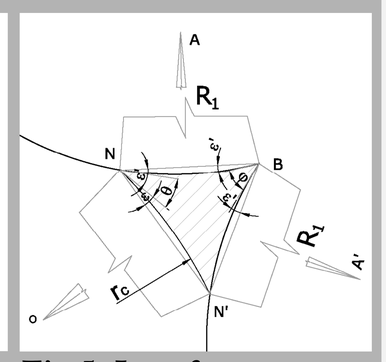


Fig 5. Interface geometry in a regular hyperbolic polygon.

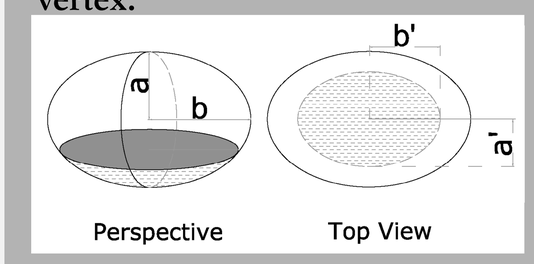


Fig 6. Interface in prolate spheroidal pore bodies.

Pore bodies are represented by prolate spheroids. Fig 6 shows the assumed interface configuration in a pore body during imbibition process.

Results

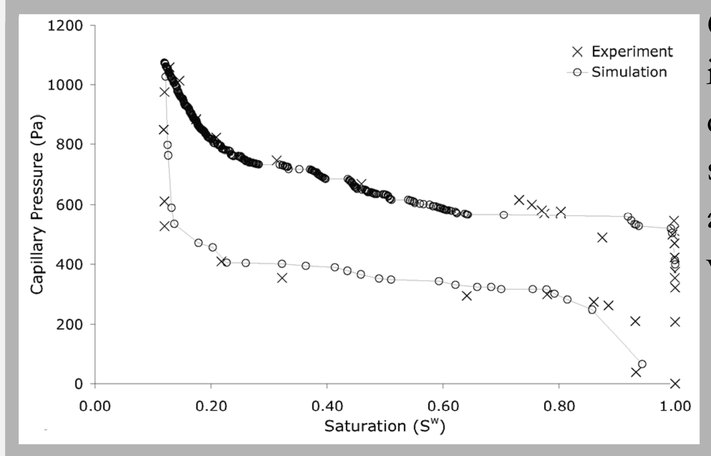


Fig 7. P^c-S^w curves for drainage & imbibition experiments in glass beads.

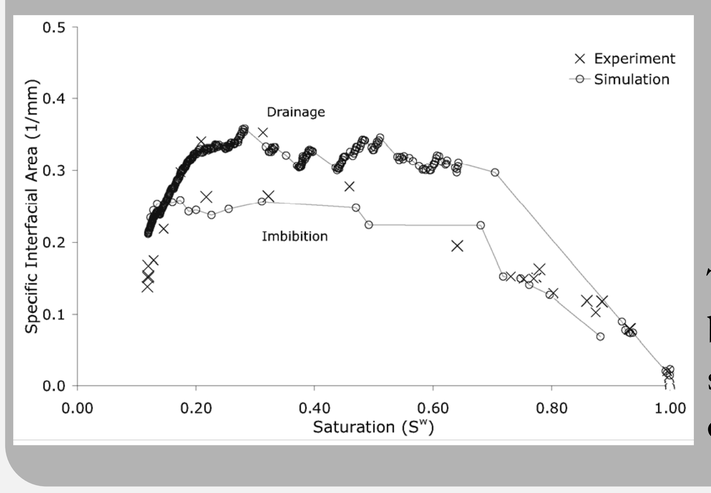
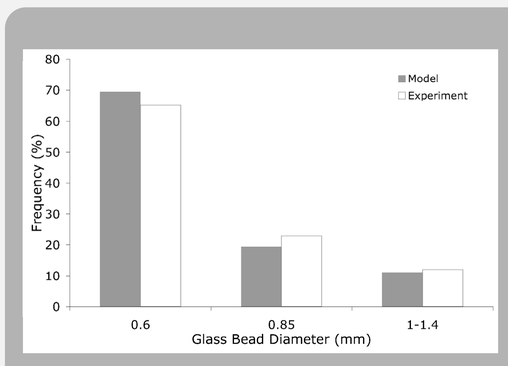


Fig 8. a^{nw}-S^w curves for drainage & imbibition experiments in glass beads.

Quasi-static drainage and imbibition experiments are done. Capillary pressure-saturation and interfacial area are simulated and compared with experiments.

There is a good agreement between experiments and simulations especially in P^c-S^w curves .

Analysis of Results



Based on frequency of shape factors for glass beads, 5-vertice cross sections are the most frequent one. We could reproduce size distribution of the beads fairly good (Fig 9). Furthermore, uniqueness of P^c-S^w-a^{nw} surface (*Hassanizadeh* & *Gray*, 1990) has been analyzed (Fig 10).

Fig 9. Comparison between grain size distribution resulted from the model and the experimental data.

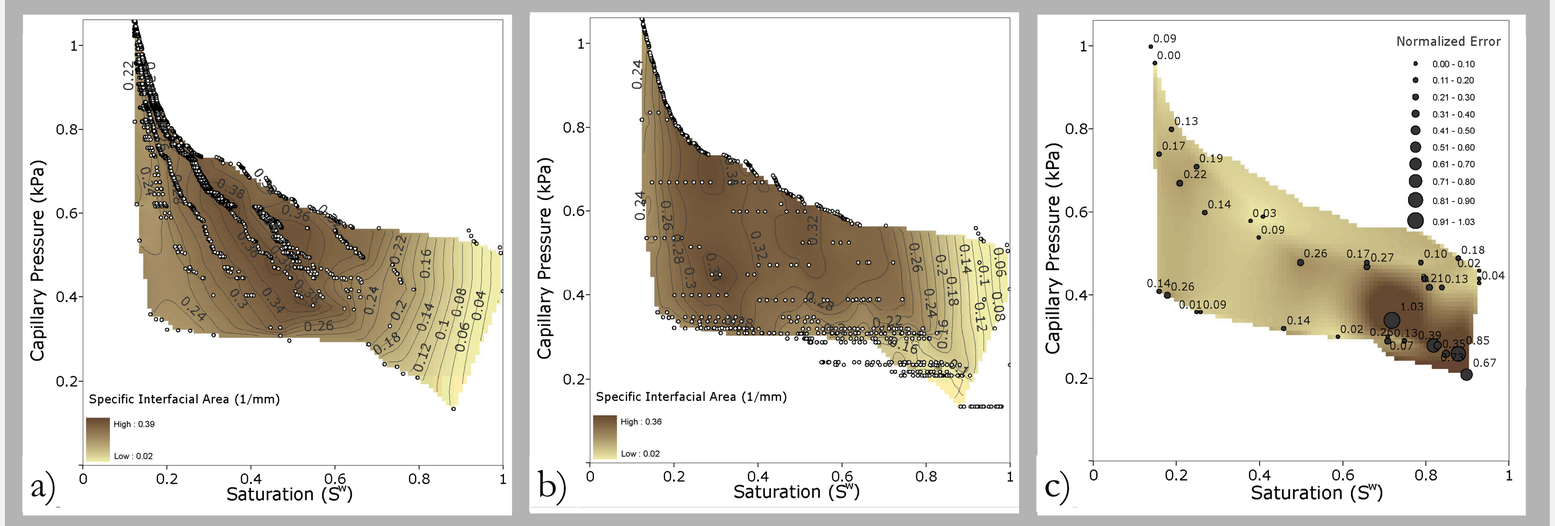


Fig 10. a) Simulated P^c-S^w-a^{nw} surface for drainage, b) Simulated P^c-S^w-a^{nw} surface for imbibition, c) Difference between simulations and experimental data normalized by experimental data.

Conclusion

-In addition to shape factor, selection of the shape of cross section (number of vertices) has a significant effect on entry capillary pressure, corner saturation, and arc menisci area.

-The pore-network model can simulate P^c-S^w and a^{nw}-S^w curves of a real porous media very well.

-Including interfacial area can reduce hysteresis dramatically, which supports the theory developed by *Hassanizadeh* and *Gray* (1990).

-We emphasize that this approach for generating cross sections based on the continuous recovery of shape factor distribution is beneficial for development of predictive pore-network models.