



Gravity-driven liquid splitting behavior at intersections and its control on infiltration

in unsaturated fracture networks

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Motivations and goals



Local flow behavior



Macroscopic flow

Visualized liquid splitting experiments

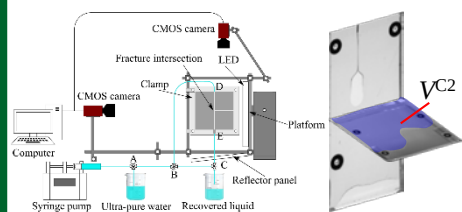
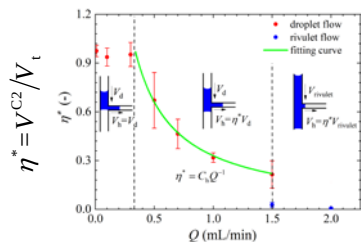


Diagram of apparatus

Intersection



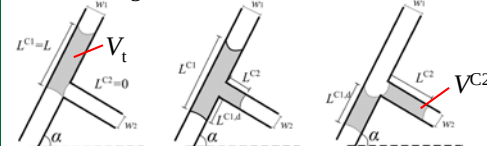
Liquid splitting relationship

(Yang et al., WRR, 2019)

<https://doi.org/10.1029/2018WR024349>

Model of liquid splitting at an intersection

- Assuming that each state is in force balance

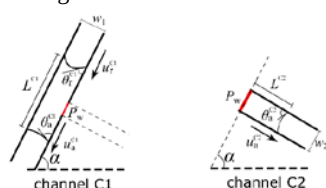


Initial state

Intermediate state

Final state

- Assuming that each state is in force balance



Force balance equations:

$$u_r^{C1}(t) = \frac{\rho g w_1^2}{12\mu} \left[\sin \alpha - \frac{2\sigma(\cos \theta_a^{C1} - \cos \theta_a^{C1})}{L^{C1} \rho g w_1} \right]$$

$$u_a^{C2}(t) = \frac{\rho g w_2^2}{12\mu} \left[\frac{2\sigma(\cos \theta_a^{C2} - \cos \theta_a^{C2})}{w_2} - \frac{\cos \theta_a^{C1} - L^{C1,d} \sin \alpha}{L^{C2}} + \cos \alpha \right] P_w$$

Mass conservation equations:

$$u_a^{C1}(t) = u_r^{C1} - u_a^{C2} w_2 / w_1$$

Dynamic contact angle model: (Voinov, 1976)

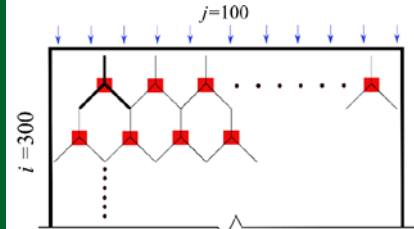
$$\theta^3 = \theta^{*3} + \xi Ca \quad Ca = \mu u / \sigma$$

(Xue et al., WRR, 2020)

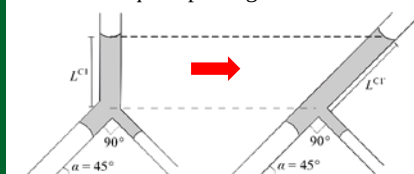
<https://doi.org/10.1029/2020WR027730>

Unsaturated flow model of networks

- fracture networks structure

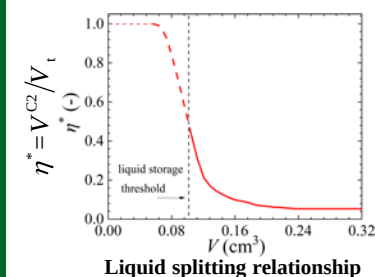


- Local liquid splitting behavior



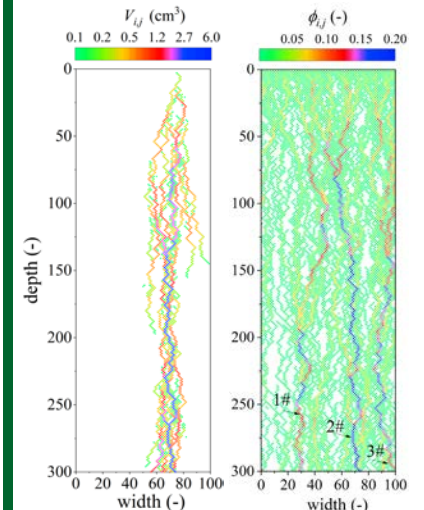
Y-intersection

Equivalent T-intersection



Liquid splitting relationship

Flow structure



Avalanche infiltration (transient)

Ratio of flow volume distribution (cumulative)

Summary

- We perform visualized liquid splitting experiments to quantify splitting behavior
- We develop a novel computational model to capture the splitting dynamics
- Macroscopic flow features are controlled by liquid splitting behavior at intersections

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