Gravity-driven liquid splitting behavior at intersections and its control on infiltration in unsaturated fracture networks

Zhibing Yang, Song Xue, Ran Hu and Yi-Feng Chen
State Key Laboratory of Water Resources and Hydropower Engineering Science, Wuhan University, Wuhan 430072, China

InterPore2021 Online
13th Annual Meeting
31 May - 4 June 2021

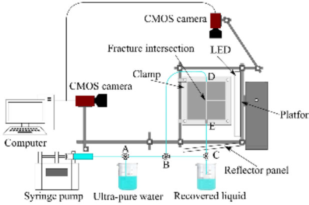
Motivations and goals

Local flow behavior

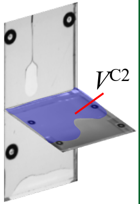
↓ ?

Macroscopic flow

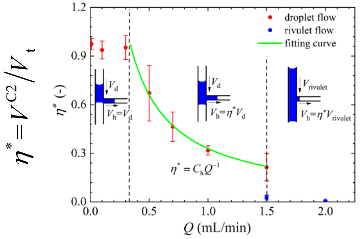
Visualized liquid splitting experiments



Exp. apparatus



Intersection

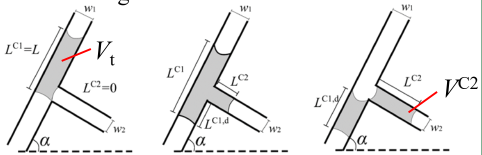


Liquid splitting relationship

(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**

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

$$u_a^{C2}(t)=\frac{\rho g w_2^2}{12\mu}\left\{\frac{\frac{2\sigma}{\rho g}\left(\frac{\cos\theta_a^{C2}}{w_2}-\frac{\cos\theta_a^{C1}}{w_1}\right)-L^{C1,d}\sin\alpha}{L^{C2}}+\cos\alpha\right\}$$

P_W

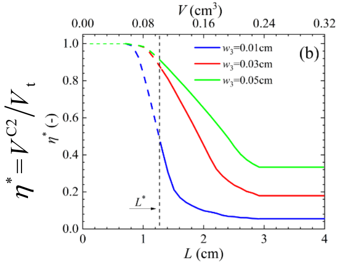
Mass conservation equations:

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

$$Ca=\mu u/\sigma$$

$$\theta^3=\theta^{*3}+\xi\, Ca$$

Dynamic contact angle

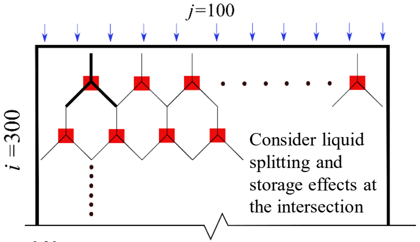


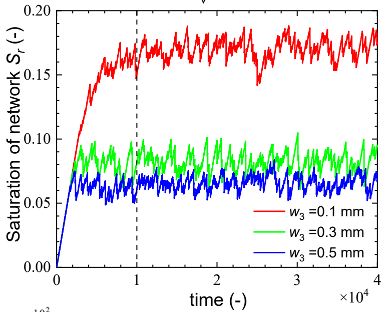
Local splitting relationship

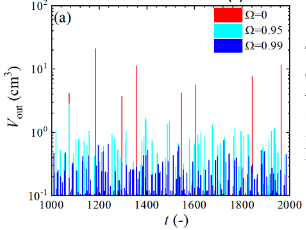
(Xue et al., WRR, 2020)
https://doi.org/10.1029/2020WR027730

Unsaturated flow model of networks

- fracture networks structure

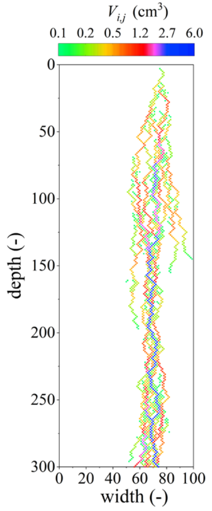




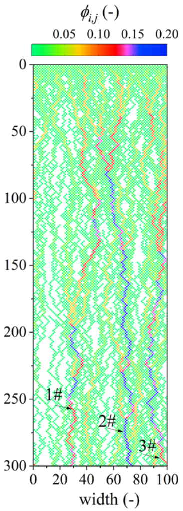


Transient Outflow volume influenced by local capillary barrier effect

Flow structure in a network



Spontaneous avalanche event



Distribution of cumulative flux

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