Numerical study of heat transfer across rough fracture surfaces

Thomas Heinze
Ruhr University Bochum, Institute of Geology, Mineralogy and Geophysics, Applied Geolology, Bochum, Germany
(thomas.heinze@ruhr-uni-bochum.de)

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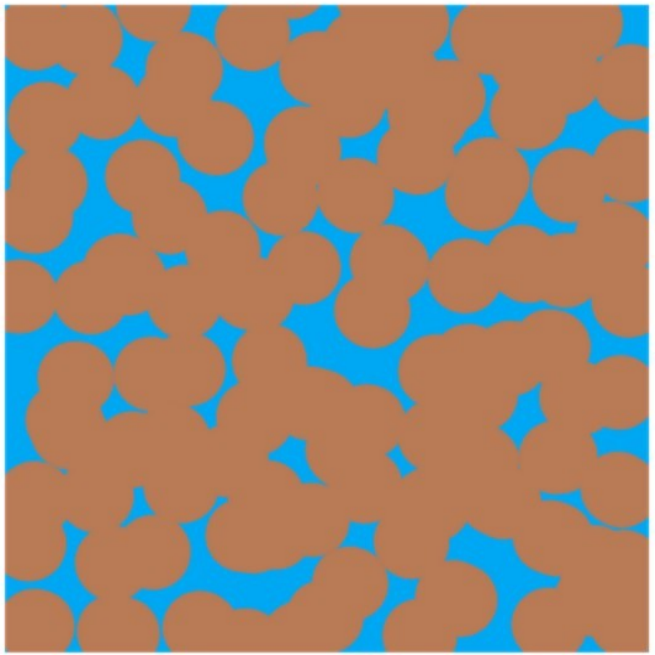
https://meetingorganizer.copernicus.org/EGU2020/EGU2020-4195.html



solid

fluid

if $T_{solid} \neq T_{fluid}$

$\hat{=}$ Local thermal non-equilibrium

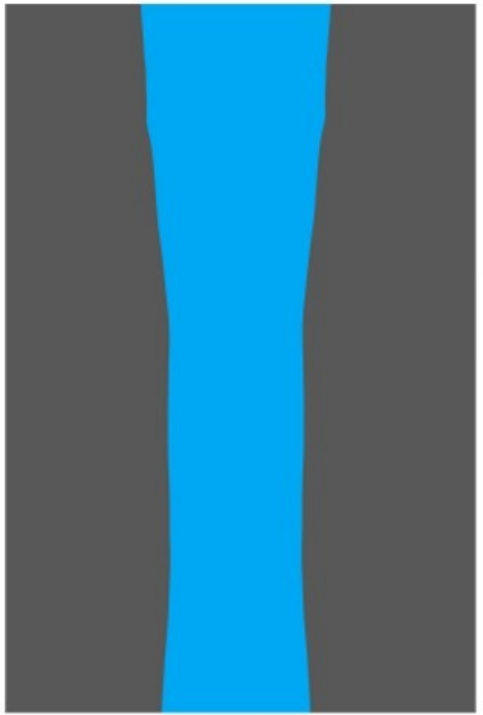
→ separate heat equ. for each phase

→ explicit heat transfer between phases

$$Q_{sf} = h \cdot A \cdot (T_s - T_f)$$

heat transfer coeff. $\left[\frac{W}{m^2 K}\right]$

spec. surface area $[1/m]$



solid

fluid

Newtons' law of cooling

$$Q_{sf} = h \cdot A \cdot \Delta T$$

- h: heat transfer coeff. $\left[\frac{W}{m^2 K}\right]$
- A: surface area $[m^2]$

h depends on:

- flow velocity
- aperture
- temperature
- thermal parameters (?)
- surface morphology (?)
- ?

Experimental findings are diverse

+ Huong et al., 2019
+ Mo et al., 2018
− Luo et al., 2019

Existing mathematical/numerical models

- Boi et al., 2017
- Heinze et al., 2017

} smooth plane

- He et al., 2019 → 'surface morphology factor'

} so far: reduced dimensional representation

Additional Complexity:

How to quantify roughness?

- joint roughness coefficient
- fractal dimension
- amplitude &/spatial parameters
- surface measures (z_2; angularity; ...)

} known relation to flow & transport (aperture; contact area)

What we did

- transient heat experiments at high flow rates
- high precision surface scans
- comparison of contaminant & heat transport
- determined >20 roughness parameters
- numerical models of LTNE heat transfer for different geometrical fracture representations

Our findings

- no correlation between roughness parameters & heat transfer
- channeling along a rough fracture is crucial
  - ↳ high flow velocity → high heat transfer coefficient
- geometrical representation of fracture influences value of h

⇒ surface morphology influences heat transfer but its effect is strongly tied to hydraulics

Model Limitations

- inconsistent boundary conditions at fluid↔solid interface
  ↳ hydraulic: no-flow vs. thermal: LTNE
- limited number of experiments
- used analytical solution for h derived for a simpler geometry

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