DTU Library

Physical mechanisms of deep bed filtration with application to the problems of petroleum industry

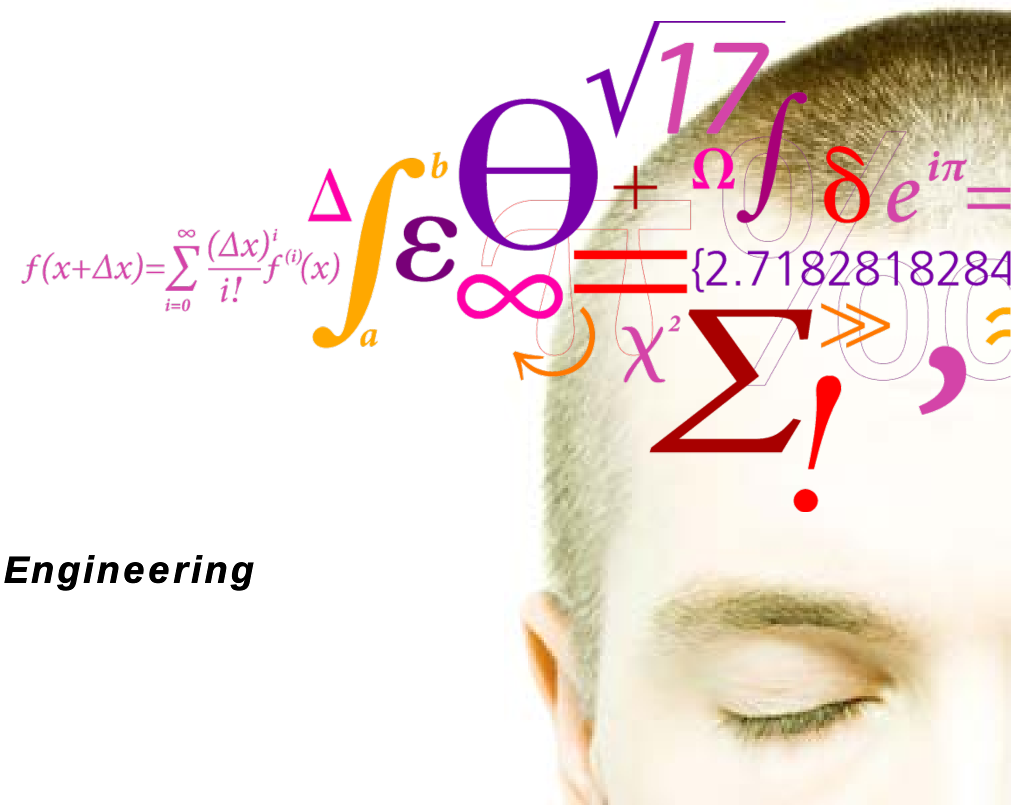
Yuan, Hao; Shapiro, Alexander; Stenby, Erling Halfdan

Publication date:
2011

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Yuan, H. (Invited author), Shapiro, A. (Invited author), & Stenby, E. H. (Invited author). (2011). Physical mechanisms of deep bed filtration with application to the problems of petroleum industry. Sound/Visual production (digital)

Physical mechanisms of deep bed filtration with application to the problems of petroleum industry



Hao Yuan
Alexander A. Shapiro
Erling H. Stenby

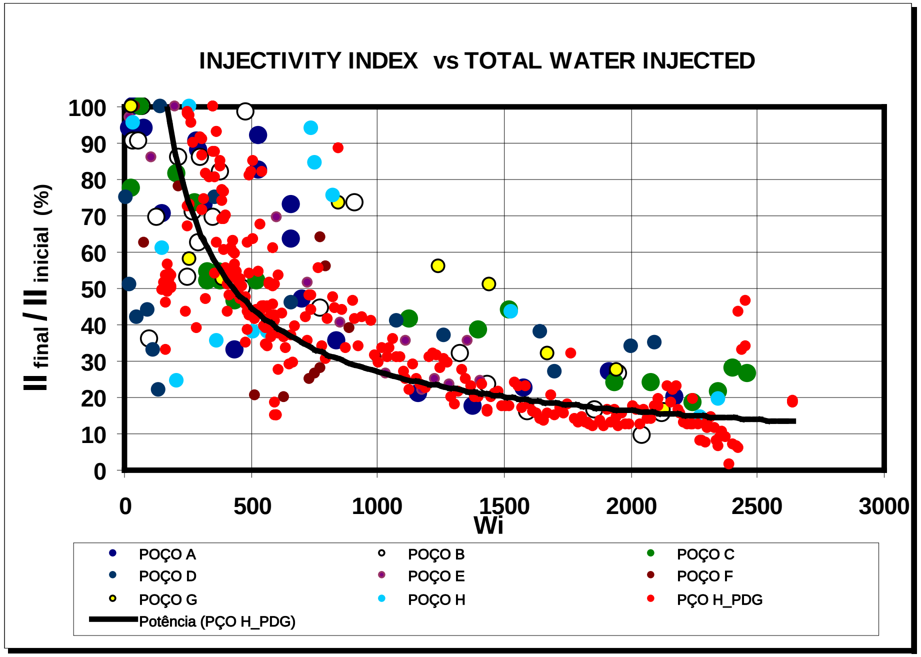
Center for Energy Resources and Engineering
Technical University of Denmark

Why to study filtration in reservoir engineering?

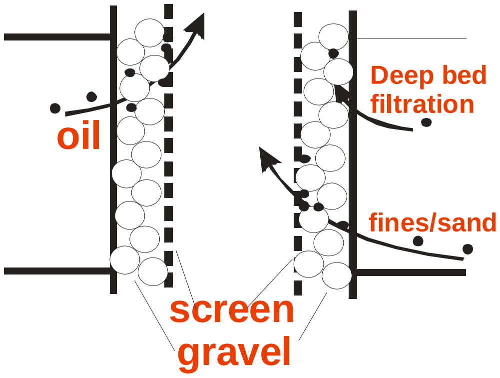
Is it a problem or an application in petroleum industry?

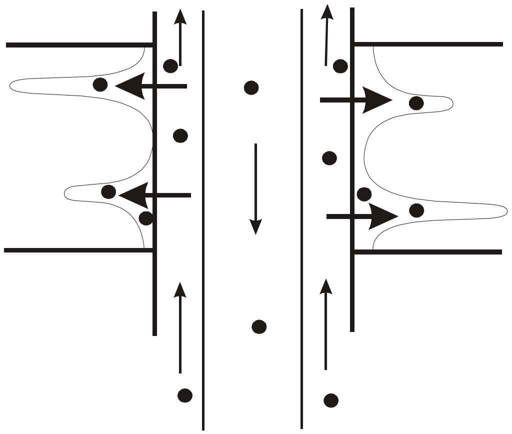
PROBLEMS AND APPLICATIONS OF FILTRATION IN PETROLEUM INDUSTRY

Problems



Productivity decline
for the gravel pack with screen





1. Injectivity decline during water injection
2. Drilling mud filtration creates filter cakes
3. Swelling and migtration of reservoir fines(clay)

Applications within EOR

- Erosion of the rock
  - Filtration in water swept zones
  - injection of carbon dioxide in chalk reservoirs

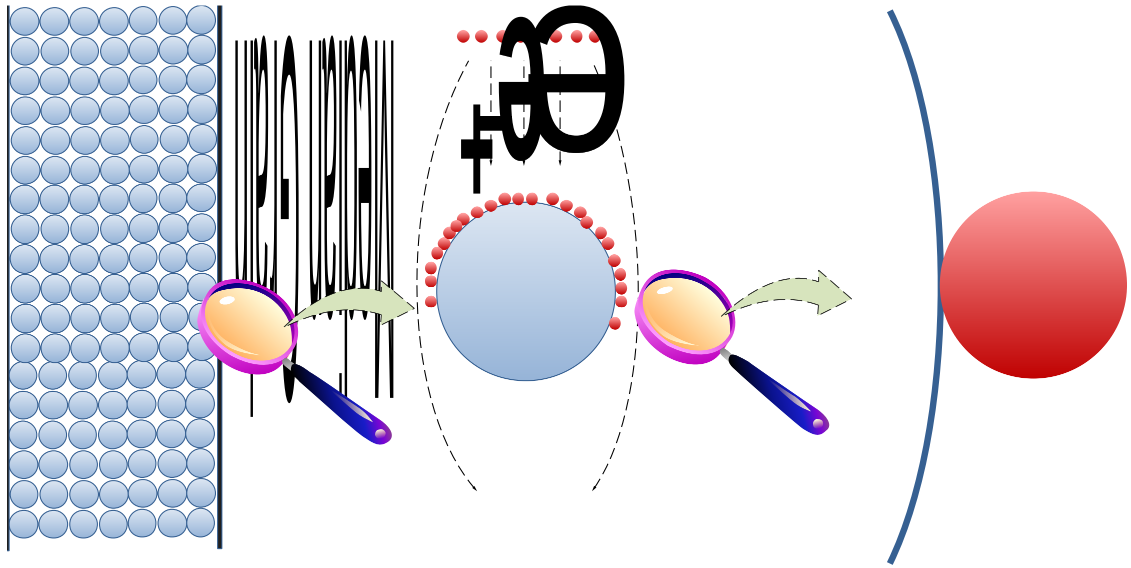
- Filtration of large molecules
  - e.g. polymer flooding, CDG flooding

- Propagation of bacteria in porous media
  - e.g. microbial enhanced oil recovery (MEOR)

Problematic filtration: damage evaluation,control
Applied filtration: flooding performance prediction
Anyway, we need a good filtration model.

CLASSICAL FILTRATION THEORY

Classical filtration theory (CFT):

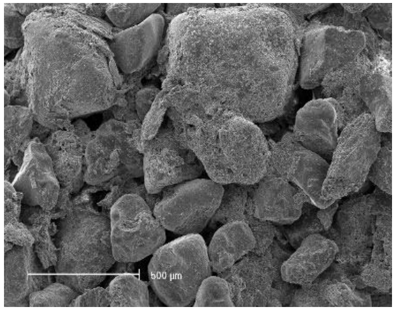


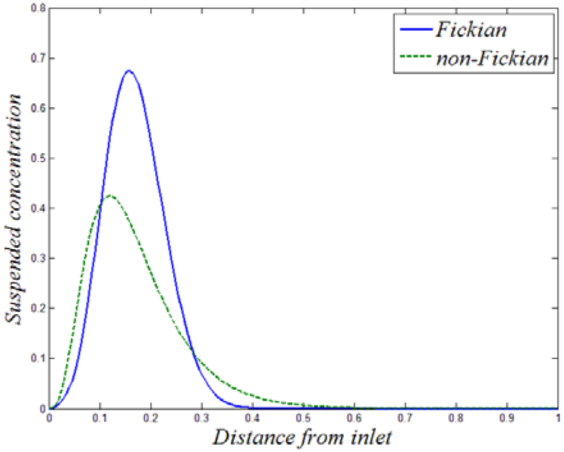
- **Bed**
- **Uniform-sized and uniform-shaped**
- **Attachment**
- **Advection dispersion equation(ADE)** [1]
- **Einstein's Random walk theory**[2]

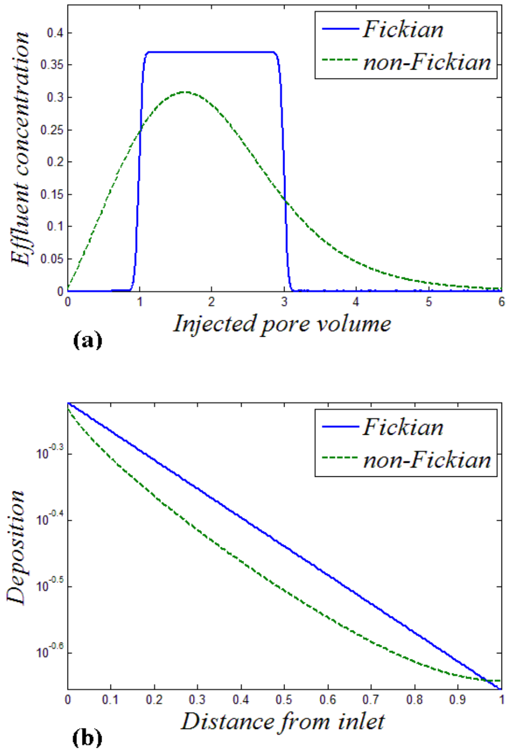
Classical filtration theory(CFT) is widely applied in the chemical industry.
Is the CFT also sufficient for the filtration in nature? Such as reservoirs?
If not, do we have the techniques for modeling such processes?

FILTRATION MECHANISMS AND RECENT ADVANCES IN FILTRATION THEORY

1. Non-Fickian transport

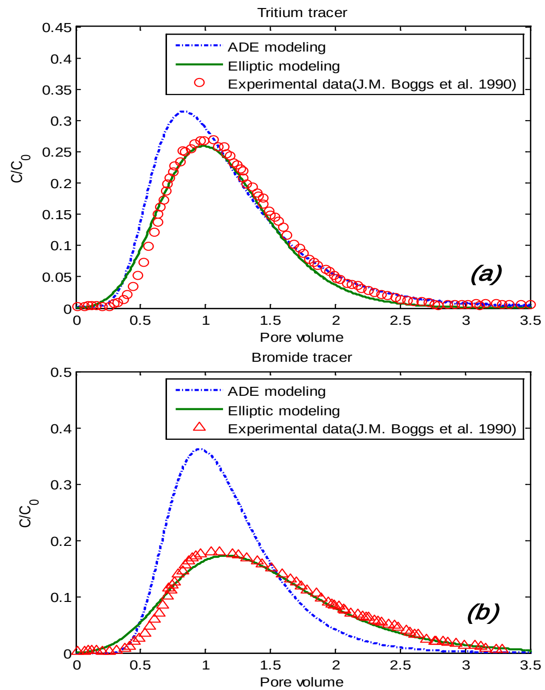




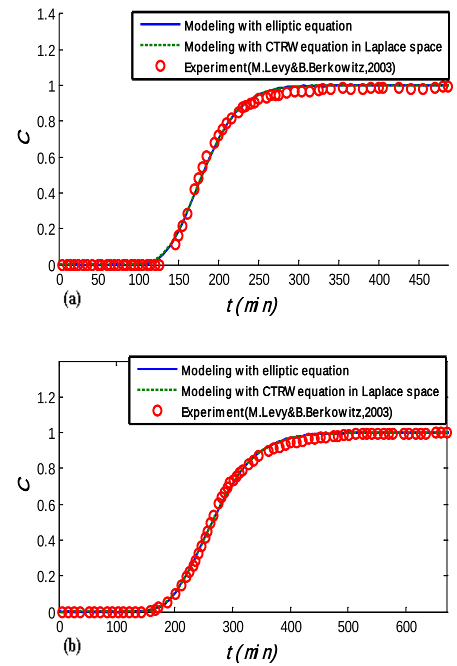


- ➢**SEM**
- ➢**Non-uniform sizes & shapes**
- ➢**Heterogeneity**
- ➢**Non-Fickian transport** [2-6]
- ➢**Continuous time random walk**
- ➢**Elliptic equation**[4-9]

Comparisons with experiments[6,7]



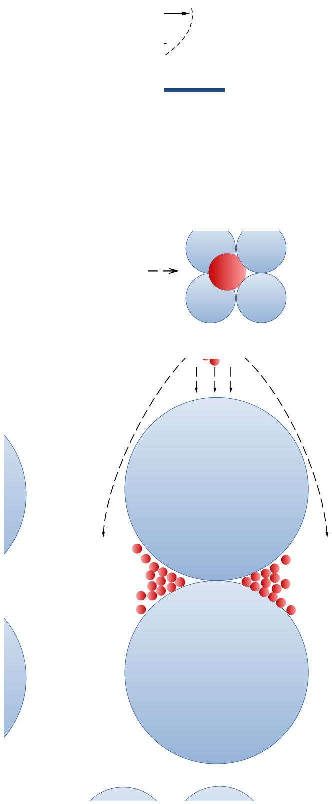
Porous media from underground formation, US millitary base



Uniform heterogeneity,(sand boxes in a sand matrix)

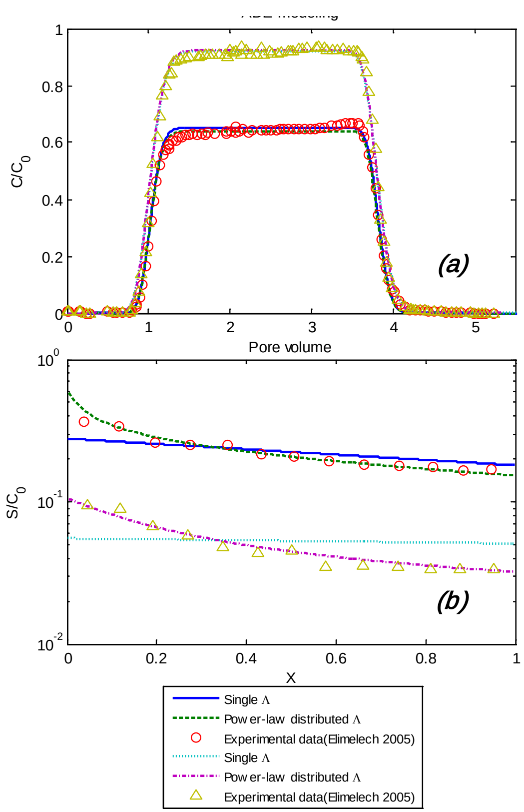
2. Polydisperse suspension[10-13]

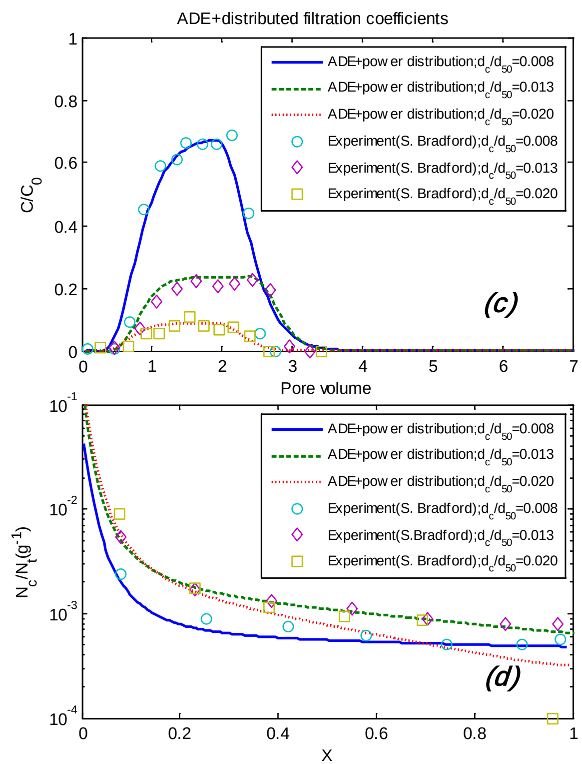
Heterogeneous particle-medium interactions



- Different sizes
- Accumulate at constrictions
- Size exclusion
- Different surface charges

Comparisons with experiments



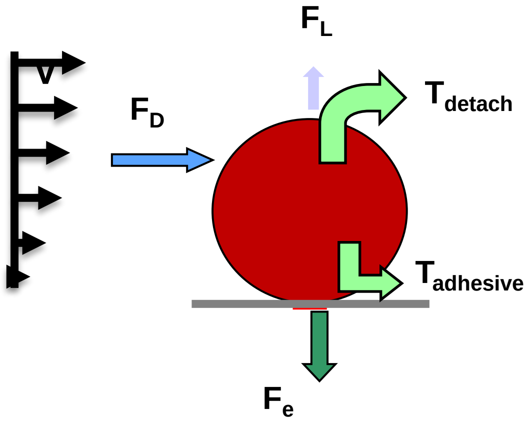


Experiments: Polydisperse colloids

Model: Distributed filtration coefficients

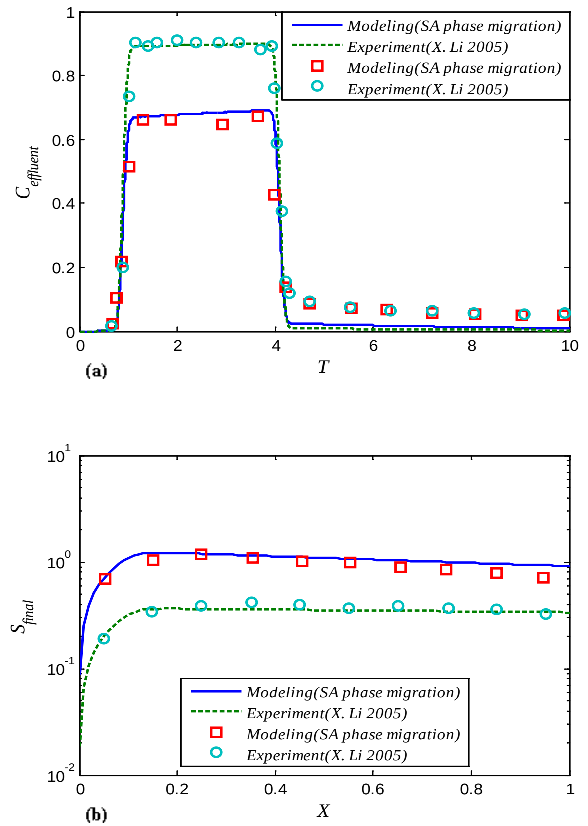
[6,7,11,12]

3. Erosion of porous media



1. **Torque balance analysis**
2. **Various forces exerting on captured particles**
3. **Balance determines whether particles to stay or release**

Comparisons with experiments



[10]

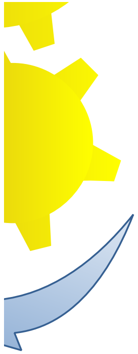
4. Maximum retention function

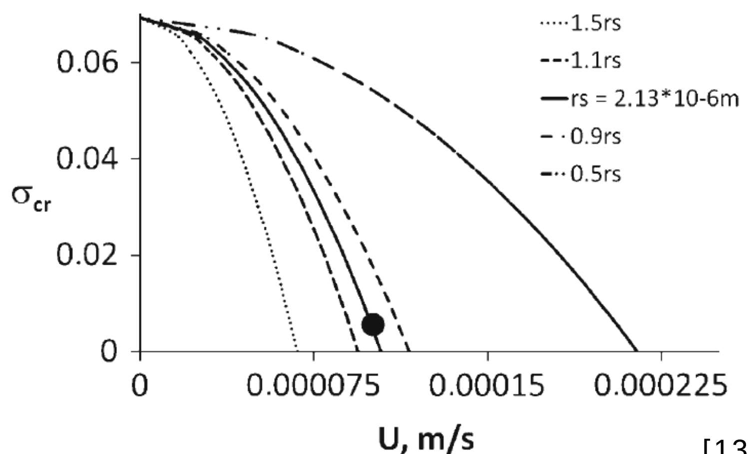
Torque balance analysis→

Express maximum retention

as a function of [13]:

1. Water salinity
2. Water velocity
3. Particle size
4. …

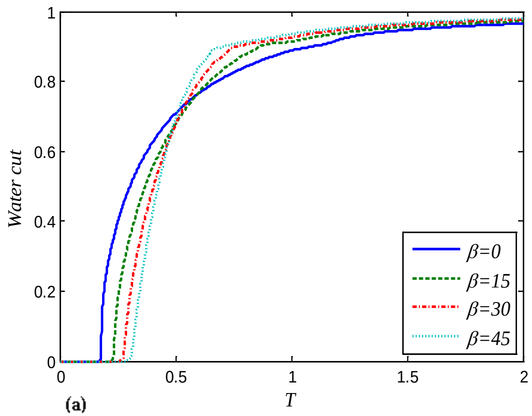


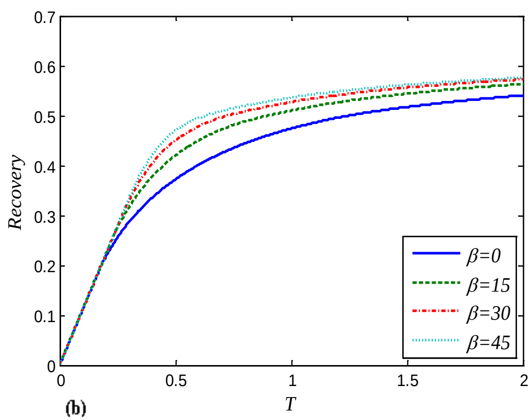


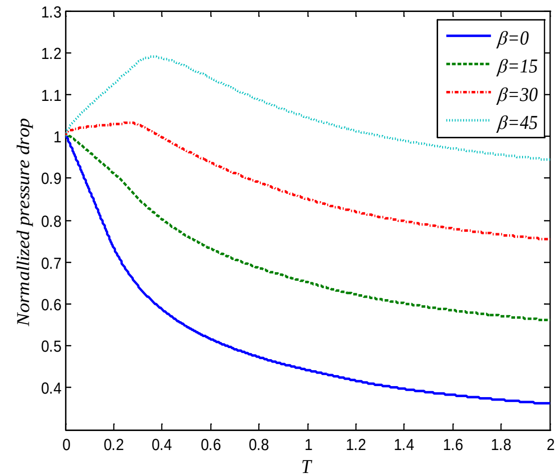
[13]

Possible Application:
Migration of fines in waterflooding for EOR

Water-cut and recovery







Here β is the formation damage coefficient.

Conclusions

- The problems and application of filtration in petroleum industry calls for more advanced models than the classical filtration theory.

- More advanced filtratration models are available for filtration in reservoirs, to account for:
  - Median heteorogeneity
  - Polydisperse suspension
  - Erosion of reservoir formation
  - Migration of reservoir fines

References

[1]. M. Elimelech, J. Gregory, R. Williams, X. Jia, Particle Deposition & Aggregation Measurement, Modelling and Simulation (Colloid & surface engineering), Butterworth-Heinemann, Oxford, UK, 1998.

[2]. A. Einstein, Investigations on the theory of Brownian motion, Dover Publications, New York, 1956.

[3]. B. Berkowitz, A. Cortis, M. Dentz, H. Scher, Rev. Geophys., 44 (2006) RG2003.

[4]. A.A. Shapiro, Physica A., 375 (2007) 81-96.

[5]. A.A. Shapiro, P.G. Bedrikovetsky, Physica A., 387 (2008) 5963-5978.

[6]. H. Yuan, A.A. Shapiro, Chemical Engineering Journal, 162 (2010) 974-988.

[7]. H. Yuan, G. Sin, Chemical Engineering Journal, 168 (2011) 635-648.

[8]. H. Yuan, Modeling reservoir formation damamge due to water injection for oil recovery, in Graduate schools yearbook, KT, DTU, Copenhagen, 2011, pp. 185-188.

[9]. H. Yuan, ParPor Particles in Pores. Stochastic Modeling of Polydisperse Transport in Graduate schools yearbook, KT, DTU, Copenhagen, 2010, pp. 209-212.

[10]. H. Yuan, A.A. Shapiro, Chemical Engineering Journal, 166 (2011) 105-115.

[11]. S.A. Bradford, S. Torkzaban, S.L. Walker, Water Research, 41 (2007) 3012-3024.

[12]. N. Tufenkji, M. Elimelech, Langmuir, 21 (2005) 841-852.

[13]. N. Tufenkji, M. Elimelech, Langmuir, 20 (2004) 10818-10828.

[14]. P. Bedrikovetsky, F. Siqueira, C. Furtado, A. Souza, Transport in Porous Media, (2010) 1-31.