PEGN 620A: Naturally Fractured Reservoirs:
Engineering & Reservoir Simulation
Fall 2009

http://www.mines.edu/~hkazemi

Thursdays: 9:00 am- 11:50 am

Instructor

Dr. Hossein Kazemi, Chesebro' Distinguished Chair in Petroleum Engineering

Office: AH 229

Phone: (303) 384-2072

E-mail: hkazemi@mines.edu

Web Page: http://www.mines.edu/~hkazemi

Office hours: Tuesdays and Thursdays 1:30 pm – 2:45 pm

Course objectives

More than fifty percent of the petroleum reservoirs are in carbonate rocks. In the Middle East, it is estimated that this number increases to seventy percent. A great number of these reservoirs are naturally fractured, e.g., Ghawar field, in Saudi Arabia, Cantarell field in Mexico, and Yates field in the USA. These are three of the largest fields in the world. The interest in such fields has grown tremendously.

Description

The course covers reservoir engineering, well testing, and simulation aspects of naturally fractured reservoirs. Specifics include: fracture description, connectivity and network; fracture properties; physical principles underlying reservoir engineering and modeling naturally fractured reservoirs; local and global effects of viscous, capillary, gravity and molecular diffusion flow; dual-porosity/dual-permeability models; multi-scale fracture model; dual-mesh model; streamline model; transient testing with non-Darcy flow effects; tracer injection and breakthrough analysis; geomechanics and fractures; compositional model; coal-bed gas model; oil and gas from fractured shale; improved and enhanced oil recovery in naturally fracture reservoirs.

Course Syllabus

- Fractures and Naturally Fractured Reservoirs (two weeks)
    - Fracture description, connectivity and network
    - Fracture properties
- Physical Principles and Flow Models (six weeks)
    - Single-phase Flow
    - Multi-phase Flow
    - Multi-component Flow
    - Dual-porosity/dual-permeability models
    - Multi-scale Fracture Model
    - Dual-mesh Model
- Transient Testing (two weeks)
    - Single-well tests
    - Multi-well test
    - Non-Darcy Flow Effects
- Tracer Injection and Breakthrough Analysis (two weeks)
    - Tracer Transport Model
    - Breakthrough Analysis
    - Streamline Simulation
- Geomechanics and Fractures (two weeks)
    - Oil and gas production from fractured shale
    - Tight gas reservoir production
- Compositional Modeling, IOR and EOR (two weeks)
    - Multi-component Model
    - Coal-bed Gas Model
    - Relevant Laboratory Experiments

Requirements

- PENG 513 or equivalent.
- Strong reservoir engineering background.
- Basic computer programming knowledge.

Exams

- Two tests and a final.

Homework Policy

Homework problems will be assigned throughout the semester. They are designed to facilitate student's understanding of the course material and its application to real world situations. The T.A. will post homework problems on the web page (www.mines.edu/~hkazemi) and Blackboard after each lecture. The student is to submit his/her homework on time to the T.A. A penalty of at least two marks (out of ten marks) for each day late will apply to any assignment or term project submitted after 4 pm on the day it is due. The homework must be typed with necessary intermediate steps included. Correct answers not supported by work will not receive credit. Additional points will be taken off when the homework is not typed, or the computer code is not submitted. All homework must be submitted before the T.A. has posted the solution on the web page or Blackboard. Any time later is a "0".

Collaboration Policy

Discussions of the assignments are encouraged; however, students must write their own code. Generally linear solver subroutines will be provided, but other than that, all other work submitted should be entirely of student's own creation. If not, this is considered academic dishonesty and will be treated as such. This treatment includes many of the potential punishments outlined in the Department academic dishonesty policies and as chosen by the faculty involved. The incident will be reported to the Dean of Student Life. A second occurrence will result in immediate reporting to the Dean of Student Life and potential expulsion from CSM and a notation in your transcript regarding academic dishonesty.

Grades

The student has one week from the time an assignment is returned to determine any possible grading errors. If after one week, an error is found, even an addition or subtraction error, there will be no change of grade. Since the class is on Blackboard, he/she will have the opportunity to check his/her grades online. If there is an error in posting, show the actual graded document to the TA. The grade will be corrected.

TAs

Sarinya Charoenwongsa

Office: AH 224

School E-mail: scharoen@mines.edu

Office hours: TBA

Jeffrey Brown

Office: AH 230

School E-mail: jsbrown@mines.edu

Office hours: TBA

Mojtaba Kiani

Office: AH 230

School E-mail: mkiani@mines.edu

Office hours: TBA

Grading

Homework: 30%

Three tests: 30%

Project: 30%

Class contribution: 10%

References

Adibrata, Bob Wikan H., Hurley, and Neil F.: "Flow-Unit Modeling Using Neural Networks, Logs, and Core in a Vuggy Dolomite Reservoir, Dagger Draw Field, New Mexico," SPWLA 44th Annual Logging Symposium, June 22-25, 2003.

Alkobaisi M., Kazemi H., Ramirez B., Ozkan E. and Atan S.: "A Critical Review for Proper Use of Water-Oil-Gas Transfer Functions in Dual-Porosity Naturally Fractured Reservoirs – Part II," IPTC 11778, to be presented at IPTC 2007, Dubai, U.A.E.

Atan, S., Al-Matrook, M., Kazemi, H., Ozkan, E., and Gardner, M.: "Dual-Mesh Simulation of Reservoir Heterogeneity in Single- and Dual- Porosity Problems," SPE 93294, Reservoir Simulation Symposium, Jan. 2005 Houston, TX.

Aziz, K. and Settari, A.: Petroleum Reservoir Simulation, Applied Science Publishers Ltd (1979).

Caers, Jef: Petroleum Geostatistics, SPE (2005).

Dickey, P. A.: Petroleum Development Geology, PennWell Books (1986).

Ertekin, T., Abou-Kassem J. H. and King, G.R.: Basic Applied Reservoir Simulation, SPE Textbook

Series Vol. 7 (2001).

Kazemi, H. and Gilman, J. R.: “Multiphase Flow in Fractured Petroleum Reservoirs,” Chapter 6 in Flow in Contaminant Transport in Fractured Rocks, Academic Press (1993) pp 267-323.

Kazemi, H., Atan, S., Al-Matrook, M., Drier, J., and Ozkan, E.: “Multilevel Fracture Network Modeling of Naturally Fractured Reservoirs,” SPE 93053, Reservoir Simulation Symposium, Jan. 2005 Houston, TX.

Kazemi, H. and Gilman, J. R.: “Engineering Aspects of Fracture Characterization and Analysis,” to be published.

Laudon, Robert C.: Principle of Petroleum Geology, Prentice Hall (1996).

Mattax, C.C. and Dalton R.L.: Reservoir Simulation, SPE Monograph Volume 13 (1990).

Narr, Wayne, Schechter, D. W. and Thompson, L. B.: Naturally Fractured Reservoir Characterization, Society of Petroleum Engineers (2006).

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Pereira, C. A., Kazemi, H., and Ozkan, E.: "Combined Effect of Non-Darcy Flow and Formation Damage on Gas Well Performance of Dual-Porosity and Dual-Permeability Reservoirs," SPE 90623, ATCE, Sept. 28, 2004, Houston, TX.

Ramirez B., Kazemi H., Alkobaisi M., Ozkan E. and Atan S.: “A Critical Review for Proper Use of Water-Oil-Gas Transfer Functions in Dual-Porosity Naturally Fractured Reservoirs – Part I,” SPE 109821, to be presented at ATCE 2007, Anaheim, CA.

Van Golf-Racht, T. D.: Fundamentals of Fractured Reservoir Engineering, Elsevier (1982).

Waite, M., Johansen, S. and Betancourt, D.: "Modeling of Scale-Dependent Permeability Using Single-Well Micro-Models: Application to Hamaca Field, Venezuela," SPE 86967, SPE Heavy Oil Symposium, March 16-18, 2004, Bakersfield, California, U.S.A.