Skoltech
Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Aysylu Askarova

PhD Program: Petroleum Engineering

Title of Thesis: Physical and numerical modeling of thermal methods of EOR and improvements of oil recovery

Supervisor: Associate Professor Alexey Cheremisin

Name of the Reviewer: S.M. Farouq Ali

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Signature:**  **Date: 19-11-20**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

The summary of issues to be addressed before/during the thesis defense

● Brief evaluation of the thesis quality and overall structure of the dissertation. This is an above-average thesis. It is planned very well; I am submitting suggestions for some changes separately. The quality of work is very good. The work consists of complex experiments, their interpretation, and numerical simulation in the context of given oil reservoirs.

● The relevance of the topic of dissertation work to its actual content The work carried out – both experimental and theoretical – follows the thesis topic closely.

● The relevance of the methods used in the dissertation The experimental techniques used in the work are the most advanced known, and show a great deal of ingenuity on the part of the candidate. The mathematical approach utilizes a numerical simulator. Much more important is the careful analysis of the experimental data for deriving the input for the simulations, and subsequently, interpretation of the simulator results to reconcile with the experimental observations.

● The scientific significance of the results obtained The thesis makes important contributions to the present understanding of supercritical water flooding, forward in situ combustion and reverse combustion. In all cases, the reaction kinetics are developed and carefully analyzed for use in numerical simulations. In two instances (OM and treatment of bitumen as a solid phase), the work points out the limitations of the current commercial simulators. Besides, the application of the processes investigated are demonstrated to selected oil reservoirs in Russia.

● The relevance of the obtained results to applications The findings and results of the experiments are used to investigate oil recovery from five reservoirs, if the relevant methods are applied there.

● The quality of publications The candidate has published and presented an impressive number of papers, unusual for most Ph.D. candidates.

The thesis should devote a chapter to the Objectives, which are lost somewhere on p. 39. Also the Conclusions should be terse and in-line with the Objectives. There should be a short section giving an overall assessment of the methods investigated. There is enough information to make judgements concerning the applicability of the methods, from the point of technical feasibility as well as the cost.

Provisional Recommendation

☒ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*

☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*

Comments on the thesis PHYSICAL AND NUMERICAL MODELING OF THERMAL METHODS OF EORAND IMPROVEMENTS OF OIL RECOVERY by AYSYLU ASKAROVA

By

S.M. Farouq Ali
University of Houston
sfarouqa@central.uh.edu

Objectives

p. 39 "The primary objectives of this study correspond to each thesis chapter:"

The objectives section of a thesis is extremely important. I ask my students to make it a separate chapter even if it is only one-page long. In this thesis, it is difficult to find the objectives reproduced below. The objectives should be written in numeric form (not bullets). The conclusions should also be short and listed numerically, with each conclusion following an objective with the same number.

The primary objectives of this study correspond to each thesis chapter:

• To determine the recovery coefficient during unique HWI experiments at the deep heavy carbonate oil field and evaluate the effect of the temperature on the oil properties, and oil displacement, to implement aquathermolysis reaction and to obtain relative permeability curves, kinetic model, and optimal operational parameters.

• To conduct the sensitivity studies and assess the application of supercritical water injection at an unconventional reservoir, to estimate the extent of chemical transformations, to implement the changes in fluid and matrix properties, viscosity, density, thermal properties, porosity. To determine the effect of the specification of initial matrix saturation with OM and number of pseudo-components and reactions taking into account the available computing capacity. To overcome the limitations of existing commercial software such as an inability to set a few different mobile liquid phases of hydrocarbons with different parameters (viscosity-temperature dependence, flowing).

• To evaluate the feasibility of the HPAI method for carbonate reservoir development, to build and validate the kinetic model. To create a 3D digital model of the combustion tube multilayer design; work of the heaters; reproduction of the processes preceding the air injection to take into account the unique phenomena such as mass-heat

transfer taking into account the properties of the medium, convection, heat losses, and secondary reactions. To carry out field-scale modeling using experimental and numerical results, to avoid the risks and uncertainties and optimize the development system.

• To analyze the results of unique forward and reverse combustion under reservoir conditions and assess their applicability, to distinguish the possible favorable conditions of reverse combustion and consider vapor phase combustion.

General Evaluation

1. p. 36 Combustion has a superior displacement efficiency over the steam injection process.(Belgrave, 2019). Maybe on the pore scale; in general, not true.

2. Wettability changes? Reason for permeability damage after water injection?

3. It is noted that the results were very sensitive to relative premeabilities which were adjusted to get a match. Not a single set of relative permeability curves is shown in the thesis. Must show a set.

4. What hot water-oil reactions were used in the numerical model? Must list them.

5. Your Conclusions are a rambling summary of results comprising two-and-a-half pages. Conclusions should be terse, numbered statements.

6. Contributions: Aquathermolysis has been previously included in steam injection modeling by several investigators.

Formatting, English

p. 5 The list is not well-formatted, the word spacing is uneven. Also note the spelling mistake: Khakimova, T.Bondarenko, A.Cheremisin, A.Myasnikov, R.G. Moore, S.A. Raj Mehta, M. Ursenbah, D. Mallory, «Adaptation of laboratory experiments on modeling of thermal methods Ursenbach.

p. 6 Members of the Integrated Center of Hydrocarbon Recovery, in face of
Not correct English
It should be “the late Dr. John Belgrave”

p. 14 the estimatesof technically recoverable crudeoil and natural gas resources are deflectable

p. 15 The given research includes

p. 19 of the industrial projects. Use “commercial” instead.

p. 21 methods possess almost 50% of the word’s EOR-based output

Fig. 3 No legend.

gasses

Pwaga, S., Lluore C., Hundseth O., Perales F.J., Idrees M.U., 2010. Comparative Study of Different EOR Methods. Incomplete reference.

p.28 During incompletecombustion, conversion of water into superheated steam with only partial heat recovery fromtheburning zone. Incomplete sentence.

p. 31 In the paper(Bhat and Kovscek, 1998)a problem of a permeability increase and cloggingdueto silica dissolution and redistribution. Incomplete sentence.

p.33 hydrous pyrolysis water promotes thermal cracking reactions and inhibit**s** carbon-carbon bond cross-linking

p. 34 ~~A lot of~~ numerical modeling studies are **Many**

p.35 Suplacy de Barcau (Romania), **Suplacu**

p. 36 278-2 7813 cp ??

would ~~filter~~ through thesample pore matrix. **Flow**

p. 47 using a proprietary pressure-feed pump. What does that mean?

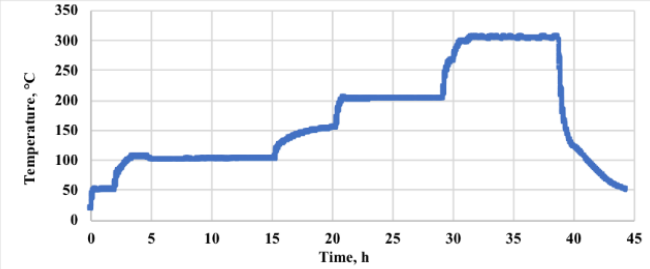

Figure 15. The temperature on the outer wall of the model in the middle part (blue) and the temperature of the water entering the reactor (brown)

No brown curve in Fig. 15, above.

p. 58 using standard methodic were

p. 75 ties leads to the increase in cumulative oil production in 247 m3. On the other hand, the calculation with KER* component leads to a reduction in oil production in 346 m3. **By**

it was defined that the specification of initial matrix ??

p. 83 has very high viscosity at low temperatures and can mobilize when temperature decrease.

p. 87 confined to the roofing of the Tournaisian stage. ??

Some figures are difficult to read, e.g. Fig. 39.
p. 105 ISC is a very perspective EOR method for improving the oil recovery factor Use **promising**

p. 113 C, which is represented by the horizontal dashed line inFigure 54. The time when each Should be 53.

p. 120 This numerical model comprehends the fluid and heat dynamics and comprises
and a result unrealistic low viscosities in this range. Incorrect grammar.

p. 122 experimental hearer profiles. ??

Potential Questions

1. p. 98. There is a large discrepancy in the moles of O2 and CO2, but the oil production shows good agreement. How is that possible?

Table 18. Mass of the products for the experiment and simulation

	Experiment	Simulation
Mass of obtained oil, g	2564.26	2485.64
Oil burned, g	220	224.62
Mass of CO_2, g	544.59	820
Mass of O_2, g	114.4	0.45
Mass of obtained water, g	2220.9	2250.9
Air injected, g	799.81	794.5
Air consumed, g	688.8	681.5

2. You do not show a single set of relative permeability curves although they are very important in simulation as you yourself say. Were relative permeabilities temperature-dependent?

3. You don't report recovery factors for the four Subsections. Where were the injection and production wells? Given the oil in place, and the calculated oil produced, the recovery factor is only a few percent of the in-place oil.

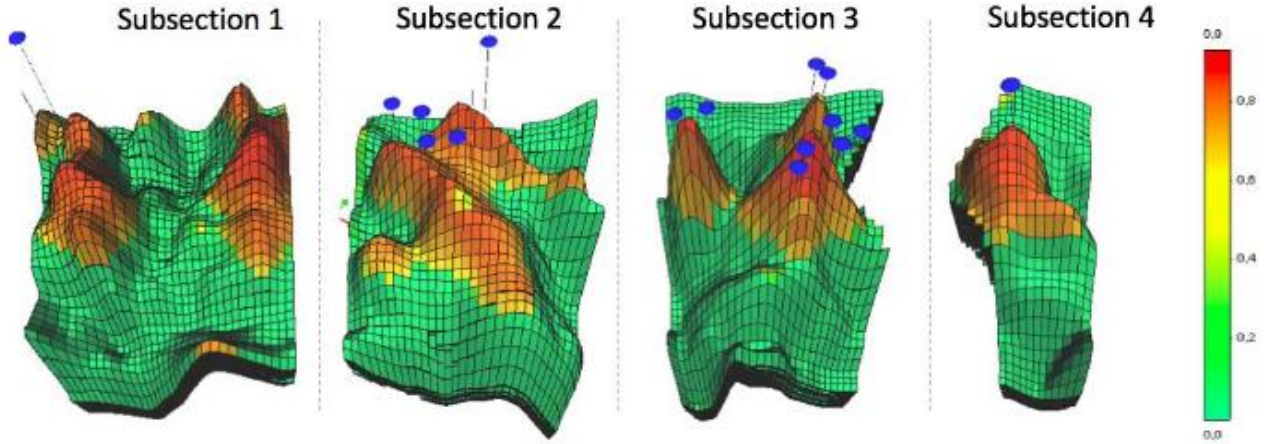

Figure 45. Oil saturation distribution of different subsections

Table 19. Characteristics of the model

Characteristics	Subsection 1	Subsection 2	Subsection 3	Subsection 4
Number of active grids	20486	40434	14447	13327
Porosity, %	11.2	12	12.1	12.1
Permeability, mD	59	84	94	82
Pore volume, m^3	8 342 974	16 288 440	6 446 607	5 581 886
Initial geological oil reserves, m^3	781 532	2 405 516	1 365 192	1 087 928

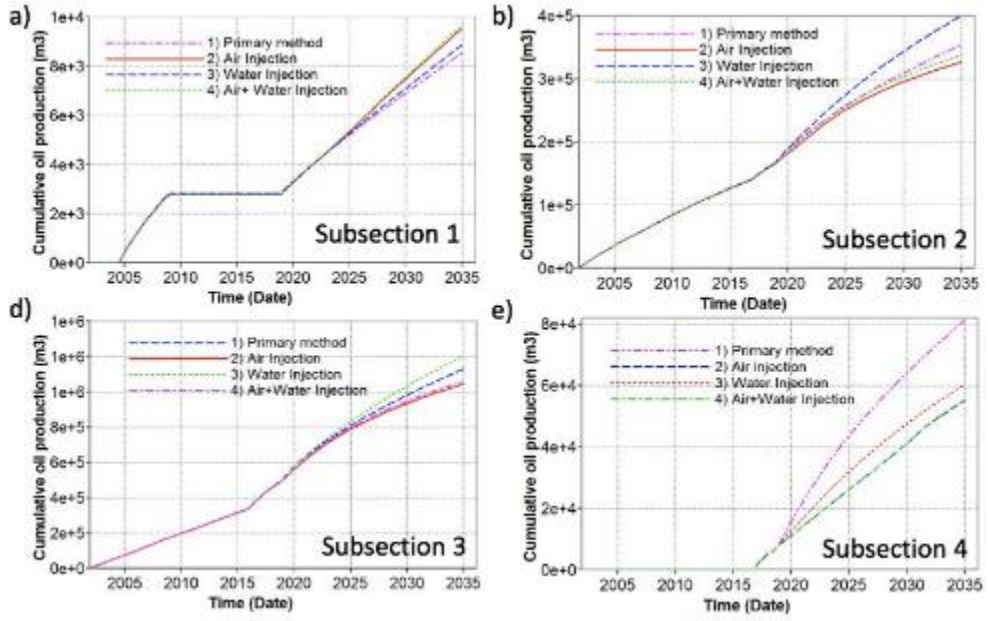

Figure 46. Cumulative oil production for 4 Subsections (a,b,d,e) and

4. The air velocity in reverse combustion experiments was 40 m/hr, which is far too high, as the resulting combustion front velocities are 0.15 to 0.35 m/hr. Was any attempt made to scale the velocity? (p. 106).
Did you test any lower velocities?