Examination Report

Higher Degree by Research Students

Examiner Name:	Professor Christoph Hermann Arns
Name of Candidate:	Strahinja Markovic
Degree:	Doctor of Philosophy
Title of Thesis:	**Application of LF-NMR measurements for characterization of unconventional hydrocarbons using machine learning**

Examiner Comments

For further guidance in writing your report, please refer to Page 1 of the enclosed "Advice for Examiners" sheet. [Note (#) the major differential between a Masters and Doctoral thesis is the scope of the project, level of critical analysis, originality and significance.]

Please comment on whether the student has adequately surveyed literature relevant to the thesis.

The candidate has a good grasp on the literature, and I found the overall logic and structure of the thesis compelling.

Please comment on whether the student has demonstrated adequate skills in the gathering and critical analysis (#) of information and report presentation.

The data analytical approach is well developed and a high level of understanding regarding the statistical techniques utilized is shown. The language is precise and concise and the topic easy to follow.

Has the student demonstrated the capacity to conceive, design and carry to completion independent research?

The work is original and the structure of the thesis logical. The approach to predict the viscosity of heavy oils is novel and the succession of chapters evolves naturally, presenting a larger body of work. The chapter two develops and tests common approaches to viscosity prediction from NMR data with various number of free parameters (2-3). A new method utilizing 4 parameters is introduced, which performs marginally better. The reader essentially learns about a set of approaches in literature and a new proposition. The following chapter then utilizes only three parameters and derivatives, so called 'feature engineering', to develop a machine learning approach to predict viscosity of heavy oils. A range of machine learning approaches are tested, and Gradient boosted regression trees and support vector regression are shown to be superior. Chapter 4 then extends the approach to heavy oil sands, where water content is an additional consideration. It is shown that machine learning approaches, in particular extreme gradient boosted approaches, are beating more traditional approaches. While micro-CT data was also utilized, the treatment of that data seems to be more peripheral. There may be potential to develop that side of the prediction further (albeit this would then be limited to laboratory).

Has the student made a substantial, original (#) and significant (#) contribution to the knowledge or understanding in the field of study?

With major heavy oil reservoirs in various countries including Canada, Russia, Venezuela, Irak as well as the United States, China and Indonesia, this is an important subject. The contribution is significant and adds to the knowledge of the discipline. The approach presented is a practical one and gives an overall understanding. More regional studies may see other feature engineering approaches (different choices of features) evolve or the ranking of ML approaches being changed.

Please comment on the quality of the publications within the body of the thesis (if applicable).

The quality of the work overall is excellent. I enjoyed reading the thesis. The publications contained in the thesis are in high-ranked journals and as such have been accepted in the discipline. I have a number of comments, which are summarized in the next section.

Please comment on the strengths and weaknesses of the thesis and any amendments which may be necessary. Your advice will be used to assist the student to modify the thesis content and presentation were necessary. For this reason, detailed comments are appreciated. Additional pages may be attached as required.

The strength of the thesis is its data analysis. Some considerations could be the influence of oxygen and related 'Curie parameters' with temperature – is the boiling point of fluids important when there are multiple components? Also, the question of SNR influence is non-trivial. How does the shape change as function or regularisation affect the feature definition and prediction performance?

Details:

- Acknowledgment is incomplete
- Eq. 1: define gyromagnetic ratio
- Eq. 5: tau is already a time; consider suffix
- p. 35, lithology-dependent NMR responses: not so sure about that – the initial amplitude is not, but the decay is influenced by internal gradients, diffusion coupling,…
- p.35, 3ms for clay-bound water; should this be 33ms?
- p.40, JC bitumen – define or provide reference
- p.42 ff., there is confusion about \omega and \omega_0 in this section
- p.42, last line: 'b' is referenced to wrong equation
- p.43, eq. (19) is for porous media; but afterwards heavy oil seem to be treated as fluids. This can cause confusion, since solid components in heavy oils may act as surface relaxation centres. Careful with the terms T2 vs T2bulk here. Is Fig. 6 refering to T2bulk?
- p.44, eq 20 & 21 use different exponents, yet beta seems to be introduced for Eq. 20 in the text
- p.46, Fig.7 tick-marks on y-axis need more resolution
- p.48: correction term has not been defined; do you need to consider oxygen effects or boiling points of different components in your model?
- p.50, reference to Khan in the Figure – provide citation to references.
- p.52, 2.2.9: what is SNR for the eperiments?
- p.53, peek at 200 degC is past the glass transition. Does the NMR signal of peek change with temperature?
- p.54, define \xsi
- p.74: how is the test set selected?
- p.77: 'T2-related' features – should this be T?
- p.81: is your training data split to carry out CV?
- p.84, Fig. 18: should this be \lambda in the second plot?
- p.103: check last paragraph.

Examiner Recommendation

Please select only one of the recommendations below:
If the thesis requires amendments the student will be given up to 3 months to complete.
If the thesis requires re-examination, the student will be given up to 6 months to make the revisions.

☐The thesis be classified as PASSED with no requirement for correction other than minor typographical or editorial matters. The Thesis Chair will require that the student correct such errors as pointed out by the Examiner;

If you have selected the above recommendation, do you consider the content and presentation of this thesis of sufficient quality to be deserving of a commendation from the Chancellor of the University?

YES ☐ NO ☐

☒The thesis be classified as PASSED after the student has made minor textual and/or structural amendments to the satisfaction of the Thesis Chair as outlined in the Examiner's Report;

☐The thesis be classified as PASSED provided the student has revised specific sections of the thesis to the satisfaction of the Thesis Chair as outlined in the Examiner's Report. The Examiner may specify this category for a thesis which requires substantive revisions that will not change the substantive conclusions of the thesis;

☐The thesis be SUBMITTED IN A REVISED FORM FOR RE-EXAMINATION by the original Examiner after further research, rewriting, reorganisation, and/or reconceptualisation. The Examiner may specify this category for a thesis which requires major, substantive amendments. In the report the Examiner shall provide detailed guidance to the student to assist revision; or

☐The thesis be classified as FAILED, without right to resubmit the thesis, on the basis that a significant amount of additional research work and/or major substantive revision will not raise the thesis to an acceptable standard.

Do you approve the release of your identity to the student? YES ☒ NO ☐
Any confidential comments not for release to the applicant may be made on a separate page and marked 'In Confidence'. Please be aware that under the Freedom of Information Act it might not always be possible to prevent disclosure of such information

EXAMINER NAME Christoph Arns

SIGNATURE DATE **24/072022**