

## Jury Member Report – Doctor of Philosophy thesis.

**Name of Candidate:** Evgenii Kanin

**PhD Program:** Petroleum Engineering

**Title of Thesis:** Asymptotic models of coupled geomechanics/fluid mechanics phenomena of hydraulic fracture growth

**Supervisor:** Professor Andrei Osiptsov

**Co-supervisor:** Professor Dmitry Garagash, Dalhousie University, Canada

**Name of the Reviewer: Prof. Sergey Stanchits**

I confirm the absence of any conflict of interest

**Date: 05-08-2022**

*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

In his Ph.D. thesis entitled *“Asymptotic models of coupled geomechanics/fluid mechanics phenomena of hydraulic fracture growth”*, Evgenii Kanin modeled propagation of hydraulic fracture in permeable rock. Evgenii took into account three different effects: (a) fluid exchange between the fracture and permeable formation; (b) turbulent-laminar fluid flow inside the fracture; and (c) the rheology of fracturing fluid, characterized by the non-zero yield stress and non-linearity of the shear stress. As a result of the modelling, Evgenii obtained a general numerical solution for the crack aperture and pressure for the semi-infinite fracture and assessed the effect of the pore fluid flow on the crack properties. Therefore, I consider the topic of Evgenii’s Ph.D. study interesting, important and potentially applicable to the field studies.

The thesis is well-written, 215 pages long, contains six chapters, including a literature review, a detailed description of all applied models, and conclusions. In the frame of Ph.D. study, Evgenii made the modelling of the fracture with pressure-dependent leak-off, the modelling of turbulent flow effects in a slick water, and modeling of hydraulic fracture driven by a Herschel–Bulkley fluid. The content of the dissertation and the implemented models are entirely consistent with the topic of the Ph.D. study, and obtained results are significant.

I have a few comments related to the text of the PhD thesis.

- Evgenii carried out modelling of fluid flow, taking into account two different crack models: semi-infinite and penny-shaped. How close do these idealized models correspond to the real hydraulic cracks created in the field conditions? Where can each of these models be applied?
- Is it possible to give at least a few examples of hydraulic fractures, in which the consideration of the fluid exchange related to the fluid pressure inside the fracture is particularly important?
- Evgenii implemented two numerical approaches for the Herschel–Bulkley rheological model of the penny-shaped fracture: accurate and approximate. Why were two numerical algorithms proposed? What are the limitations of each approach? Which one can be considered best?
- Some important details are omitted in the manuscript, such as the derivation of the pressure-dependent leak-off rate and how this fluid exchange mechanism fits into the numerical algorithm for a radial hydraulic fracture. They are given as references, but I recommend Evgenii to add them into the thesis for the completeness.
- Finally, I would recommend Evgenii to add to his thesis, for example, in the Conclusions section, some ideas regarding how the developed models can be validated using laboratory and/or field data. I assume that verified models may be of a higher value for possible industrial application than unverified ones.

Overall, despite the above remarks, Ph.D. study certainly represents a significant step forward in modelling of hydraulic fracture propagation in permeable rock. Evgenii Kanin has demonstrated this with his presentations at four International conferences and publications as the first author in three papers in the Q1/Q2 ranking journals.

Summarizing the above, I believe that the candidate is definitely qualified for a Ph.D. degree.

#### **Provisional Recommendation**

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